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WEEKLY 5 November 2022

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Boosting your immune system through diet

COUNTDOWN TO COP27

Everything you need to know about the climate summit

SPECIAL ISSUE

SECRETS OF THE PHARAOHS

How science is transforming our understanding of ancient Egypt



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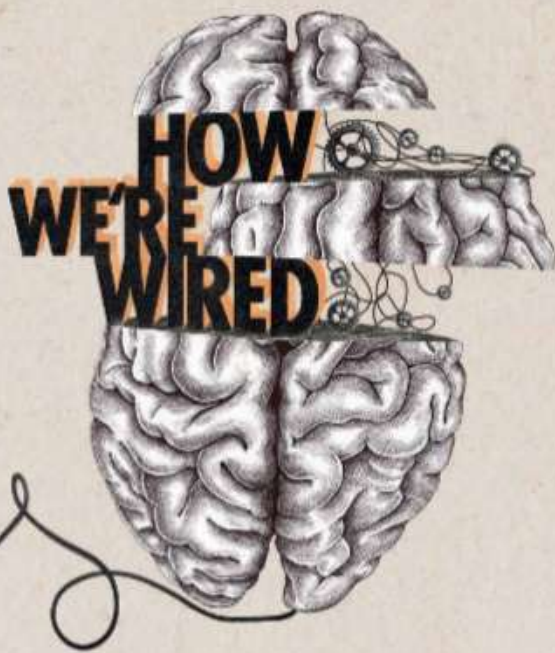
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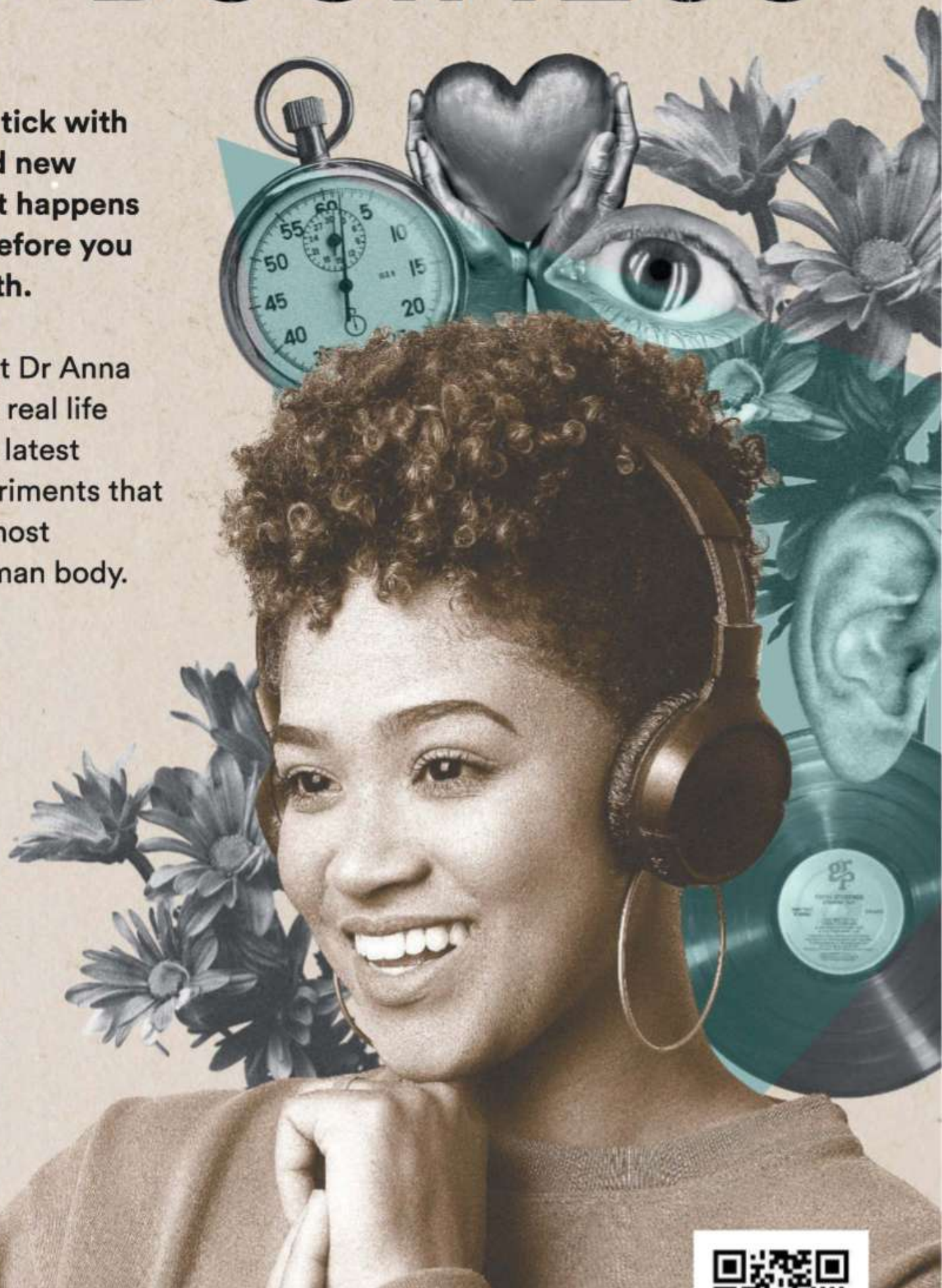
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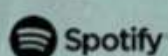
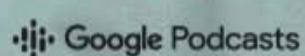
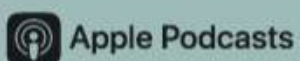
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Virtual event

Memory, the brain and who we are

How do our brains store past experiences to make us who we are? Why can memories feel so real? Are there such things as “true” and “false” memories? Psychiatrist Veronica O’Keane offers a new way of thinking about our personal experiences. Watch online at 6pm GMT/ 1pm EST on 10 November. Also available on demand.

newscientist.com/events

Podcast

Weekly

The team listens to the quacks and grunts produced by a host of animals, including sea turtles, that were previously thought to be silent. The discovery of such widespread vocalism hints that the trait stretches back at least 400 million years. There is also news that turmeric supplements have been linked to liver damage in a small number of people. Plus, how to measure time with a quantum watch.

newscientist.com/nspod

Video



DONOVAN WRIGHT

Historic birth First bison born in the wild in the UK in modern times

Newsletter



KATERYNA KONI/SCIENCE PHOTO LIBRARY

Health forecast Are you ready to know your risk of heart disease?

Video

Baby bison

Head to our YouTube channel to meet the first bison born in the wild in the UK for thousands of years. The calf’s unexpected birth came as part of a rewilding project in south-east England, in which three European bison were released onto a patch of ancient woodland earlier this year to explore the animals’ potential to benefit woodland ecosystems.

youtube.com/newscientist

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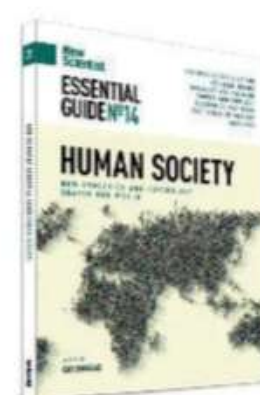
Health Check

This month, British firm Genomics announced plans to trial DNA testing that can predict whether someone is at a genetically higher risk of experiencing conditions such as heart disease. Health reporter Clare Wilson asks whether we are emotionally prepared to receive such news.

newscientist.com/health-check

Podcast

“Are you 100 per cent sure these aren’t all ducks?”



Essential guide

How did evolution and psychology shape human society? We differ from most other animals in that we cooperate with strangers as well as with family members. Learn about how this happened – and the tensions it has created – in the latest *New Scientist Essential Guide*. Available to purchase now.

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Everyday riches

New techniques are giving us striking insights into the daily lives of ancient Egyptians

IT IS one of those strange quirks of history that Howard Carter discovered Tutankhamun's tomb exactly 100 years after Jean-François Champollion cracked ancient Egypt's hieroglyphics. Champollion's breakthrough in 1822 unlocked the civilisation's rich written archive, while Carter's discovery in 1922 offered an unadulterated view of pharaonic opulence.

It is unlikely 2022 will be remembered as a pivotal year in Egyptology, but that doesn't mean the field is stuck in a rut. As we report on page 38, archaeologists now have the tools of modern science at their fingertips. Their discoveries may seem relatively humdrum at first glance, but they could prove transformative for our understanding of ancient Egypt.

A look back at the breakthroughs of 1822 and 1922 shows us why. One of the most famous ancient Egyptian texts we could read once we understood hieroglyphics was the Book of the Dead (see page 34) and Tutankhamun's treasures showed us a grand pharaonic tomb in vivid detail

"The discoveries may seem humdrum, but they could be transformative"

(see page 32). Throw in Egypt's mummies and the world's most iconic tombs – the pyramids – and it is easy to assume the ancient Egyptians were fixated on death.

Today's archaeologists tend to focus on the day-to-day of ancient Egyptians' lives. Doing so provides a more down-to-earth

perspective, making them seem more like us. We can now gain insights into the way skilled artists worked millennia ago, for instance, and even reconstruct the sights and smells of the landscapes they occupied, bringing us closer than ever to experiencing ancient Egypt.

This isn't to say archaeologists have turned their backs on the pharaohs. Some are convinced that an untouched royal tomb even grander than Tutankhamun's still awaits discovery. If the tomb of Queen Nefertiti is ever found, researchers will surely have another year as important as 1822 and 1922 to celebrate. Until then, by putting the lives of ordinary ancient Egyptians in the spotlight, Egyptology has made sure it remains relevant to a 21st-century audience. ■

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Marketforce UK Ltd **Tel** +44 (0)33 0390 6555

Syndication

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One year print subscription (51 issues) UK £270
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Post New Scientist, Rockwood House, Perrymount Road, Haywards Heath, West Sussex RH16 3DH

© 2022 New Scientist Ltd, England. New Scientist is published weekly by New Scientist Ltd. ISSN 0262 4079. New Scientist (Online) ISSN 2059 5387. Registered at the Post Office as a newspaper and printed in England by Precision Colour Printing Ltd



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Quantum navigation

Positioning device could be used to augment GPS **p12**

Impact of poaching

Rhino horns have shrunk over the past century **p13**

Industrial revolution

Drought may have kick-started the switch to coal **p20**

Neutrino laser show

Neutron stars shoot out two beams at each pole **p21**

Machine learning

AIs get smarter if they are told to think step by step **p23**



PILAR OLIVARES/REUTERS

Lula's supporters celebrate in Rio de Janeiro

authority that ensures Brazil's policies are in line with its Paris Agreement goals.

His administration is expected to set new climate targets after they were rolled back by Bolsonaro, says Natalie Unterstell, a Brazilian climate change policy expert at the think tank Talanoa.

Rebuilding environmental institutions and removing illegal groups from the Amazon will be challenging, particularly with a divided congress and a narrow electoral mandate, environmental campaigners warn.

"Stopping the slaughter of indigenous peoples and the devastation of the Amazon will require countering powerful gangs and, very often, the interests of allies and supporters in local governments and the Parliament," said Marcio Astrini, executive secretary of the Brazilian Climate Observatory, in a statement.

A series of bills proposed by Bolsonaro, including the legalisation of mining on Indigenous land, could also be approved in the two months before Lula takes office on 1 January.

Lula's victory should be a boon not just for the Amazon, but also for Brazilian universities, healthcare and broader science, where Bolsonaro has cut funding and filled senior posts with unqualified allies.

He slashed public funding for science and technology research by almost half, to its lowest level in more than a decade, and accused public research institutions of falsifying data.

As *New Scientist* went to press, Bolsonaro hadn't spoken publicly to acknowledge the result. Before the election, he made unfounded claims that the voting system was vulnerable to fraud and hinted that he wouldn't accept defeat. ■

Politics

Lula wins Brazil election

The defeat of Jair Bolsonaro, who oversaw rampant deforestation, has been hailed as a win for the Amazon, reports **Luke Taylor**

DEFENDERS of the Amazon rainforest were overwhelmed with relief on 30 October as Luiz Inácio Lula da Silva narrowly secured Brazil's presidency.

Lula, who was president from 2003 to 2010, beat incumbent Jair Bolsonaro by just 1.8 per cent of votes in the divisive presidential election. The tight victory could save the Amazon just as it has reached a crucial tipping point, say Brazilian environmentalists.

"During the past four years, the Amazon has been threatened, attacked and destroyed as the government openly promoted environmental crimes," says Erika Berenguer at the University of Oxford, who was in tears as she spoke to *New Scientist*.

"It was like having to silence a scream inside you every day as you watched the object of your life, your career and passion destroyed," she says. "Lula's election is a victory not only for the region, but for humanity and life itself."

Deforestation soared to a 15-year high as Bolsonaro publicly promoted the development of the rainforest, diluted environmental regulation and gutted key environmental institutions of funding and expertise.

The amount of the Amazon being cleared is now nearly 75 per cent higher than when Bolsonaro took office in 2019, and the 13,000 hectares lost in 2021 was the largest annual figure since 2008.

In contrast, Lula has campaigned to protect the rainforest and deforestation plummeted by 72 per cent between 2004 and 2016, when Lula and his successor, Dilma Rousseff, were in power.

"Lula's election is a victory not only for the region, but for humanity and life itself"

Lula has pledged to remove illegal miners and ranchers clearing the Amazon. Among his more ambitious proposals are the subsidisation of sustainable farming, the creation of a ministry dedicated to Indigenous peoples and a national climate change

Climate change

Urgent warnings ahead of COP27

On the eve of the UN climate talks in Egypt, a series of reports illustrates how much further countries must go to avoid catastrophic global warming, finds **Madeleine Cuff**

IN THE holiday resort of Sharm El Sheikh in Egypt, the stage is being set for COP27, the next round of UN climate talks, which kicks off on 6 November.

As delegates prepared to head to the summit, a flurry of sobering reports released last week reminded the world that greenhouse gas concentrations are rising and hopes of delivering on the promises of the 2015 Paris Agreement are fading fast.

First came the stark but unsurprising news from the World Meteorological Organization (WMO) that atmospheric concentrations of planet-warming carbon dioxide, nitrous oxide and methane hit a record high in 2021 and have continued to rise throughout 2022.

Atmospheric CO₂, responsible for about 66 per cent of global warming since 1750, hit 415.5 parts per million in 2021, the WMO said. Meanwhile, methane registered the largest single-year increase since researchers started keeping records 40 years ago.

"The continuing rise in concentrations of the main heat-trapping gases, including the record acceleration in methane levels, shows that we are heading in the wrong direction," said Petteri Taalas, secretary-general of the WMO, in a press release.

An atmosphere clogged with warming gases is triggering increasingly severe climate impacts around the globe, with 2022 having brought extreme heatwaves, storm surges and devastating flooding to many parts of the world.

An assessment by an international coalition of scientists of 35 "planetary vital signs", such as ocean acidification, deforestation rates and Arctic sea ice loss, found that 16 are at record extremes and are "flashing red" on the climate dashboard (*BioScience*,

NAPLES POLICE DEPARTMENT/UP/SHUTTERSTOCK



2022 has seen extreme climate impacts, such as Hurricane Ian in Florida

a deal that nations would submit bolder proposals to cut emissions within a year to put the world on track to meet the Paris Agreement goals. But since then, just 26 countries have come forward with updated plans, with the new pledges collectively shaving less than 1 per cent off projected 2030 greenhouse gas emissions.

"There's a huge gap between where the current promises are taking us and what we actually need," says Anne Olhoff at UNEP. "[The report] basically says that not a lot has happened since last year, and if we are really serious about this, that needs to change dramatically and immediately."

Tensions running high

It is the job of COP27's Egyptian hosts to persuade countries that they must slash emissions faster in the short term to keep longer-term net-zero goals within reach, a tough ask at a time when the global economy is under strain and goodwill between nations is in short supply (see interview, opposite).

The plan is to focus the summit on implementation – in other words, driving real action on the ground in countries around the world. This means accelerating the roll-out of green energy, drawing up plans to close coal plants early and cutting methane emissions as fast as possible.

But tensions are already running high. Key Egyptian diplomats have accused high-income countries of "backsliding" on their promises for climate finance that would help lower-income nations move forward with emissions cuts.

doi.org/gq4t9z). The results prompted the team to warn that humanity is "unequivocally facing a climate emergency".

Yet many fear such warnings are being ignored after two UN reports confirmed that the world is still on course to blow through temperature goals set under the Paris Agreement.

The plans countries have drawn up would see carbon emissions fall by 3.6 per cent by 2030 compared with 2019 levels, according to an analysis by the UN's climate change secretariat published on 26 October. That is well below

the 43 per cent drop needed to meet the 1.5°C temperature target set out in the Paris Agreement.

In fact, the plans put the world on course for warming of about 2.5°C above pre-industrial levels by the end of the century, the UN concluded, perhaps even more if lower-income nations don't get further financial support to cut carbon. Climate scientists warn that any warming above 1.5°C risks triggering severe and irreversible changes to ecological systems.

"The science is clear and so are our climate goals under the Paris Agreement," the UN's climate lead, Simon Stiell, said in a statement. "We are still nowhere near the scale and pace of emission reductions required to put us on track toward a 1.5°C world."

A day later, a report from the UN Environment Programme (UNEP) reached much the same conclusion. It warned that current national plans to cut carbon emissions leave no "credible pathway" to limit global warming to 1.5°C, with a 2.6°C rise by the end of the century billed as the most likely outcome.

The last UN climate summit, COP26 in Glasgow, UK, ended with

3.6%

Fall in carbon emissions in 2030 vs 2019 based on countries' plans

43%

Fall in carbon emissions needed to meet the 1.5°C temperature target

2.5°C

Projected temperature rise by 2100 based on countries' plans

SOURCE: UNFCCC

Interview: Mohamed Nasr

'This is a reality check'

Egypt's chief climate negotiator tells **Madeleine Cuff** that COP27 will focus on making sure existing promises are kept

The thorny issue of “loss and damage”, which would see richer countries pay reparations to vulnerable nations feeling the brunt of climate impacts, looks set to be a major flashpoint. The US has agreed to talks on the issue, but many countries want to see cash on the table at COP27.

“There is a huge gap between where the current promises are taking us and what we actually need”

“Developing countries really want this on the agenda, [but] developed countries are a bit afraid, because it opens the door to questions of liability and compensation,” says Jen Allan at Cardiff University in the UK.

Yet even amid a tough political backdrop, markets are moving in the right direction. On 27 October, for the first time, the International Energy Agency (IEA) said that demand for fossil fuels is set to peak within 15 years.

Even if efforts to phase out fossil fuels aren't stepped up, demand for coal will start declining within a few years and oil demand will level off by 2035, according to the IEA's latest World Energy Outlook analysis. Crucially, even gas demand is forecast to plateau from the end of this decade.

A peak in fossil fuel use would mark a historic turning point for the global economy, finally uncoupling GDP and fossil fuel use for the first time since the industrial revolution. It also spells good news for the climate: global emissions from the energy sector are now forecast to peak by 2025 as a result of slowing demand, the IEA has said. But in what is now a familiar refrain, it also said countries must do more to speed up the energy transition or risk runaway rates of warming. ■

COUNTRIES should prioritise delivering on existing plans to cut carbon emissions rather than drawing up fresh strategies to achieve the 1.5°C temperature goal, according to one of Egypt's leading climate diplomats.

The COP27 summit will be a “reality check” to make sure that climate pledges already made on UN stages are being delivered in nations around the world, according to Mohamed Nasr, Egypt's chief climate negotiator.

At last year's COP26 summit in Glasgow, UK, countries pledged to put forward bolder carbon-cutting plans – so-called nationally determined contributions, or NDCs – within a year. At the time, this was seen as a vital collective promise that would fulfil the summit's aim of keeping the 1.5°C temperature goal alive.

Yet, under the leadership of Egypt, the COP27 conference isn't set to be a crunch moment for nations to deliver on that promise. Rather than conjuring up “nice numbers that make headlines”, Egypt will instead focus on generating the financial and technical support that vulnerable countries need to start cutting emissions immediately, says Nasr.

“What we are hearing from people who are impacted on the ground is ‘enough planning and planning and coming back with new initiatives and development plans’... How much of it is happening on the ground? This is a reality check,” he says.

“We can have too many plans,” says Nasr. “But if we do not deliver on them, then we are not really serious about dealing with climate change.”

A sign welcomes visitors to the COP27 conference area in Sharm El Sheikh, Egypt



Profile

Mohamed Nasr is Egypt's chief climate negotiator and a diplomat at the Ministry of Foreign Affairs

The focus on implementation is a subtle shift away from the priorities of the UK's COP presidency, which ends on 6 November as COP27 gets started. Under the leadership of COP26 president Alok Sharma, the UK was laser-focused on urging countries to move faster on cutting emissions and to adopt longer-term net-zero targets.

For Egypt, financial support for more vulnerable nations is a priority. High-income countries are still yet to fulfil a long-overdue commitment to channel \$100 billion a year of climate finance to less wealthy

nations. The deadline was 2020, but the latest estimates suggest the pledge won't be met until next year at the earliest. More support to help countries adapt to the escalating impacts of climate change has also been promised, but not yet delivered.

“Yes, let's push for enhanced NDCs, but how can developing countries enhance their NDC when they are not seeing funding even for their original NDC? This is something that we are hearing loud and clear,” says Nasr. “We need to deliver on the finance score.”

He admits that the consensus-based UN climate process is a “fragile regime”, particularly in the wake of the turmoil of the past year, which has seen spiralling global inflation, an energy crisis sparked by Russia's invasion of Ukraine and rising tensions between the US and China.

In that context, convincing world leaders to turn up in Sharm El Sheikh would be a victory of sorts, says Nasr. “Success on the ground, at this very difficult time, is having a substantial number of heads of states coming and confirming that climate change is still their priority.” ■



SAYED SHEASHA/REUTERS

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Subvariant 'soup' may drive wave

The coronavirus subvariants BQ.1.1 and XBB may spread more readily than the original omicron variant and could evade prior immunity to some extent, writes **Carissa Wong**

DESPITE winter approaching in the northern hemisphere and mixed vaccine availability worldwide, the numbers of reported covid-19 cases and deaths are declining globally. As of the week ending 23 October, reported cases were down 15 per cent on the previous seven days, while deaths had declined by 13 per cent.

However, a soup of new coronavirus subvariants looks set to drive a new wave of infections across Europe and the US this November, says Christina Pagel at University College London. Many other parts of the world are already experiencing, or coming out of, these waves.

Until recently, the covid-19 pandemic jumped from one variant to the next, such as from delta to omicron, says Moritz Gerstung at the University of Heidelberg, Germany.

"Typically, a new variant came and displaced all or most other preceding lineages very quickly, but now we're seeing a real mix of subvariants, with much more incremental changes that result from them acquiring a portfolio of mutations all over the viral genome," he says.

High levels of immunity due to vaccination or from previous infection are creating a selection pressure towards immune-evading variants.

Earlier in the pandemic, quick lineage jumps occurred as the coronavirus got better at infecting cells, says Gerstung. Now that ability is optimised, smaller mutations are helping the virus to evade immunity, he says.

Perhaps one of the most concerning subvariants is BQ.1.1, a descendent of the omicron BA.5 subvariant BQ.1. Between 3 and 9 October, BQ.1 and its descendants made up 6 per cent of the SARS-CoV-2 coronavirus sequences



MARK KERRISON/PICTURES VIA GETTY IMAGES

submitted to the GISAID global viral database. They have now been detected in 65 countries.

In France, BQ.1.1 already makes up around half of the sequenced cases and it has probably reached that point before the rest of Europe, but perhaps not much earlier, says Gerstung. BQ.1.1 cases roughly double every week, so it quickly becomes widespread, he says.

BQ.1.1 may also account for most of the covid-19 infections in Africa, where the subvariant was first identified in Nigeria in July. However, limited testing makes it hard to know, says Gerstung.

"Of all the 'soup' variants, BQ.1.1 and XBB look like the ones with the potential to beat out the rest"

The subvariant's rapid spread is probably due to six mutations that alter the surface of the spike protein that the virus uses to enter cells. Vaccines rely on this protein to bring about an immune response.

Early research suggests that BQ.1.1's mutations enable it to evade neutralising antibody responses generated by vaccines

A poster promoting covid-19 vaccinations in Slough, UK

and prior infections. "We see a fairly decent correlation between the number of mutations in different lineages and their rate of spread," says Gerstung. "BQ.1.1 has among the highest number of immune-evading mutations."

BQ.1.1's advantage is more likely to be due to its ability to evade immunity than to it being better at infecting cells, according to both Pagel and Gerstung.

Another omicron subvariant, XBB, has particularly taken hold in India, where it was first identified, and now accounts for up to a third of the country's reported SARS-CoV-2 infections.

"Out of all of the current 'soup' variants, BQ.1.1 and XBB look like the ones with potential to beat out the rest," says Pagel.

XBB arose from a so-called recombination event in which two descendants of the omicron subvariant BA.2 infected the same cell and exchanged genetic material, forming a hybrid subvariant with seven key mutations for evading immunity –

more than any other subvariant currently in circulation.

Being infected by two or more subvariants at once may result in a higher risk of severe illness. However, the bigger concern is that recombination could drive mutations that may cause new waves of covid-19 infections, says Pagel.

XBB quickly spread from India to Singapore, where – with its descendent XBB.1 – it drove a wave of infections that peaked around mid-October. It is now travelling through the rest of Asia.

Between 3 and 9 October, XBB comprised up to 1.3 per cent of the sequences submitted to GISAID. It has now been detected in 35 countries.

According to the World Health Organization (WHO), there is early evidence of a higher reinfection risk with XBB, compared with other omicron subvariants, among people who caught covid-19 before omicron became dominant.

It is unclear whether an XBB infection protects against BQ.1.1, or vice versa, because they have very different mutations, says Gerstung.

"My personal opinion is an infection with BQ.1.1 should provide good immunity against the ancestral forms of the virus [BA.2 and BA.5] closely related to BQ.1.1, but XBB is very different to BQ.1.1, so it's hard to say," he says.

To date, there is no substantial evidence to suggest that XBB or BQ.1.1 cause more severe illness than the original omicron variant, according to the WHO.

And while BQ.1.1 is currently more prevalent than XBB, this may not mean that the former will outcompete the latter.

"There is a scenario where they could both become widespread," says Gerstung. ■

Technology

Quantum navigation device could augment GPS

Karmela Padavic-Callaghan

A QUANTUM device that can determine its position in three dimensions is more accurate than non-quantum versions and could be used by vehicles to navigate if GPS stops working.

One way to keep track of something's position is with an accelerometer, which is a small device that is found in everything from phones to drones. These work by detecting changes in movement and therefore position.

It has been known for decades that quantum effects could be used to make accelerometers more accurate, but most built so far can only measure in one dimension. Philippe Bouyer at the French National Centre for Scientific Research and his colleagues have now built a quantum accelerometer that can measure in three.

The device works by firing three lasers – in the length, width and height directions – at rubidium atoms cooled to near absolute zero. At this temperature, quantum effects come in to play so that the laser light causes the atoms to ripple like waves, the nature of which depends on the device's movements. By analysing the ripple patterns, the device can calculate the acceleration in the laser's three directions.

The atoms can be controlled extremely precisely, which makes the device very accurate, says Bouyer. The team found that if acceleration measurements were used to calculate the device's position in space while on a shaking table, after a few hours, it would be inaccurate by around 20 metres. In the same time, a standard version would be off by 1 kilometre (arxiv.org/abs/2209.13209).

Large vehicles that absorb lots of vibrations, such as ships, could be a good match for this new technology, says John Close at the Australian National University in Canberra. ■

Astrophysics

JWST shows ancient galaxy may be merging with another

Alex Wilkins

ONE of the oldest known galaxies might actually be two galaxies in the process of colliding, according to new observations from the James Webb Space Telescope (JWST).

In 2012, the Hubble Space Telescope spotted what seemed to be the oldest galaxy we had found, MACS0647-JD, thanks to the gravity from a cluster of galaxies called MACS0647 bending and magnifying its light, a phenomenon called gravitational lensing.

MACS0647-JD formed about 13.3 billion years ago, or just 400 million years after the big bang, although JWST has since found galaxies that are potentially older.

Light from MACS0647-JD is bent and magnified by a cluster of galaxies, called MACS0647, so it appears in multiple places in this image (shown in boxes)

Now, Tiger Yu-Yang Hsiao at Johns Hopkins University in Maryland and his colleagues have captured light from MACS0647-JD using JWST's powerful infrared sensors and found that it appears to be either two galaxies that are

13.3

Age, in billions of years, of the galaxy MACS0647-JD

merging or a galaxy with two distinct clumps of stars. There is also a third galaxy nearby.

Galaxies so distant from us, about 13.3 billion light years away, are usually too dim to observe. "Due to gravitational lensing from the galaxy cluster, the light will bend and magnify [MACS0647-JD] by eight times, so it's actually eight times brighter than it was," says Hsiao.

One of the clumps of stars

in MACS0647-JD looks larger and bluer than the other, which indicates that it formed more recently than the redder clump. This is because the longer it takes light to travel to us, the more its colouration shifts to redder spectral hues.

Hsiao and his team don't have enough data to say for sure whether they are seeing galaxies merging, but if it is confirmed to be such an event, it would be the oldest known example of this (arxiv.org/abs/2210.14123).

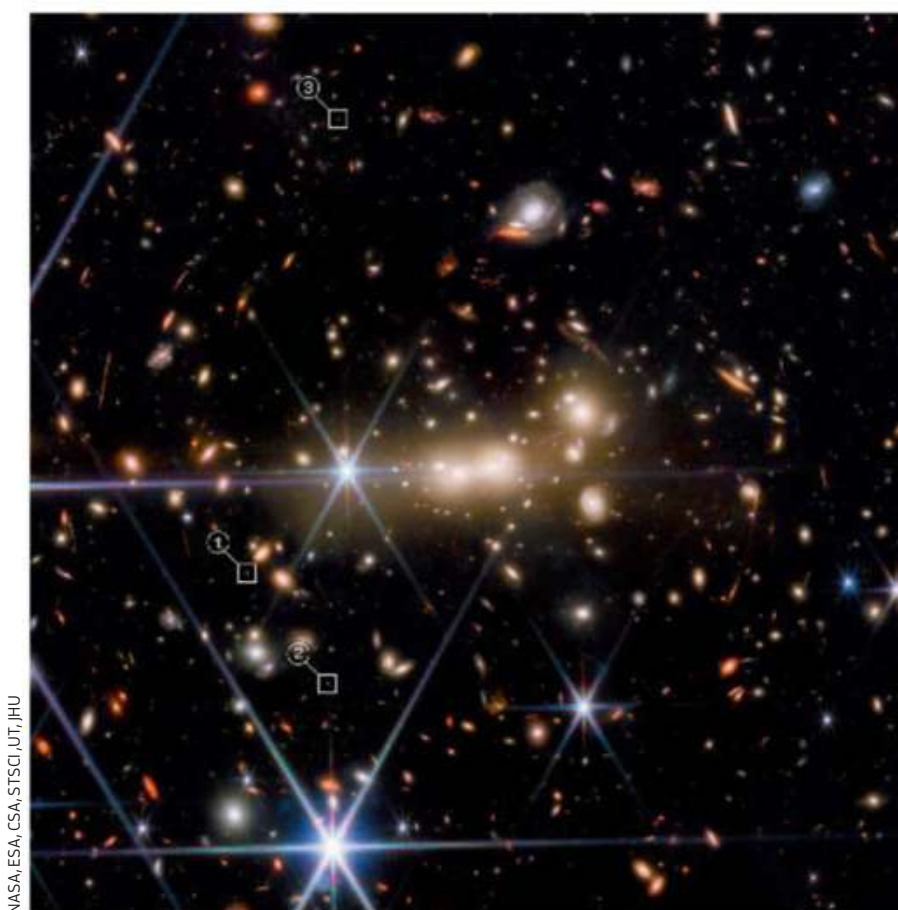
Even if MACS0647-JD is just one galaxy made up of two clumps, it could provide information on how the first galaxies formed. It came into being in the reionisation era of the universe, just after the first stars began to appear.

The universe has vastly expanded since these early galaxies took shape, so they are all very far away. "Although other galaxies have been observed out to these early times, you can count them on one hand," says Simon Dye at the University of Nottingham, UK. "They are rare and therefore each one gives us valuable insight into galaxy formation in the very early universe."

However, we will need a larger sample of such objects across the sky to work out exactly when and how the first galaxies began to form, he adds.

Hsiao and his team hope to learn more about MACS0647-JD with another JWST observation in January next year.

On that occasion, it will take photos at two longer wavelengths of light and gather spectroscopic data for MACS0647-JD, which will allow better estimates of age and composition. ■



NASA, ESA, CSA, STScI, JHU

Conservation

Rhino horns have got smaller

Archive photos suggest poaching may have driven evolutionary changes in five species

Christa Lesté-Lasserre

RHINOCEROS horns appear to have become significantly smaller over the past 130 years, probably as a result of poaching.

Oscar Wilson at the University of Helsinki in Finland and his colleagues analysed 80 profile-view photographs of five rhino species dating from 1886 to 2019, which rhino experts worldwide had uploaded to a database. They used image software to estimate each rhino's horn size relative to its body size and found a gradual decrease over time (*People and Nature*, doi.org/gq5xgs).

Most of the photographed rhinos had been born in the wild, but were living in zoos or sanctuaries at the time of the photos, such as the Indian rhinos (*Rhinoceros unicornis*) pictured here. One photo in the collection showed former US president Theodore Roosevelt with a black rhino (*Diceros bicornis*) he killed in 1911 (inset). ■



Physics

Stellar smash could reveal quark matter

GRAVITATIONAL waves created when two neutron stars collide may contain evidence of a previously unseen type of matter made of quarks.

Neutron stars form when massive stars run out of fuel and collapse. They are densely packed with neutrons, each of which contains three quarks held together by the strong nuclear force. When two neutron stars merge, their particles are so forcefully smashed that the quarks may be able to leave their neutron confinement and form a type of matter called quark matter. These mergers also result in space-time rippling with gravitational waves.

Grant Mathews at the University

of Notre Dame in Indiana and his colleagues have used computer simulations to work out how gravitational waves could reveal the presence of quark matter in merging neutron stars.

The researchers simulated two neutron stars colliding to see what frequency of gravitational waves would be produced in different situations, such as at different temperatures and densities. They found that when quark matter formed, the gravitational waves would have a set of frequencies peaking at about 3 kilohertz – a clear sign to look for.

In 2017, the Laser Interferometer Gravitational-Wave Observatory (LIGO) spotted gravitational waves

emanating from a merger of two neutron stars. However, Mathews says that the detection only captured waves with some frequencies. This was sufficient to determine that a merger had taken place, but wasn't enough to decisively pinpoint what happened inside the stars.

Some people suggest that quark matter inside neutron stars behaves similarly to perfect conductors of electricity, while others posit that quark matter is an exotic fluid that

sloshes inside the stars with zero viscosity, says Mathews.

His team's simulations account for some of these scenarios, so they could be compared with future measurements of gravitational waves. He presented the work at the International Symposium on Origin of Matter and Evolution of Galaxies in Hanoi, Vietnam, on 26 October.

"There are a lot of exciting things coming in the next two years. All the detectors have been upgraded, they will all measure more frequencies and we will be able to learn more," says Veronica Dexheimer at Kent State University in Ohio. ■
Karmela Padavic-Callaghan

3 kHz

Frequency of gravitational waves emitted by quark matter forming

Urban planning

Large cities increase segregation

Lack of mixing between high and low-income people in US cities seen in location data

Alex Wilkins

PEOPLE living in large cities are more segregated, and mix less with those from different socioeconomic backgrounds, than people in small towns, according to an analysis of anonymous phone data from more than 9 million people in the US.

A long-standing premise of urban design is that cities encourage interactions between different economic groups and so lead to less segregation. One common way to measure this is to look at where people live and their corresponding economic status.

Measurements like these seem to support the idea of cities enabling mixing, but some argue this static snapshot is incomplete and needs to include how people interact when they aren't at home.

Now, Jure Leskovec at Stanford University in California and his colleagues have used smartphone data on 1.6 billion interactions between 9.6 million people in more than 382 US towns and cities to show that the largest cities in fact cause more segregation between people from different socioeconomic backgrounds.

First, Leskovec and his team looked at where each phone,

representing a person, was located at around 2am, when they were likely to be at home sleeping.

"From this, we infer their income, their socioeconomic status, and then we look during the day, as these cell phones move around, how often these cell phones cross paths," says Leskovec.

The researchers defined crossing paths as two people being in a 50-square-metre area within a 5-minute period. They

Big cities like Los Angeles have relatively high levels of segregation

tried other definitions, changing the space and time boundaries, but it didn't alter the findings.

They found that their interaction-based measure of segregation was 38 per cent lower, averaged across all areas, than a static measure of segregation, indicating that studies may have overestimated segregation when only considering home location.

But they also found that segregation was 67 per cent higher in the 10 largest cities they looked at than in the smallest, defined as having fewer than 100,000 people (arxiv.org/abs/2210.07414).

Leskovec thinks this is because cities have so many places to go. "This basically allows people to kind of bucket themselves into more fine-grained buckets. The more buckets you have, the more equals to yourself you can find because you slot yourself in the appropriate bucket," he says.

The least-segregated locations were places like museums and shopping centres that people frequently visit. One way of reducing divisions between people of high and low income could be to build such places between diverse neighbourhoods to act as a "bridge" between two groups, says Leskovec.

"What is new and interesting in what they're doing is the use of mobile phone data," says David Manley at the University of Bristol, UK. "That large kind of spatial data set means that they're able to capture the population movements in a way that we haven't been able to do before."

However, the data set isn't detailed enough to say whether people are interacting or just being in the same space, he says, and different data sets could be needed to get that level of detail. ■



TIMOTHY SVOPE/ALAMY

Technology

Using AI to train robot dogs makes them cheaper

AN AI has been used to train a small robot dog to keep its balance while using a robotic arm to perform cleaning tasks. The hardware cost a total of \$6300 – less than a tenth of the price tag of the robot dogs built by US firm Boston Dynamics.

Deepak Pathak at Carnegie Mellon University in Pennsylvania and his colleagues trained their

AI to smoothly coordinate the movements of a four-legged robot with an arm attached to its back while a human operator directed the robot's general activity.

The team first trained the AI to control the robot's legs independently from the arm, before training it to coordinate leg and arm movements. The AI learned on its own to bend and stretch certain legs to help maximise the reach of the robot's arm as it tossed cups into a waste bin or wiped a whiteboard with an eraser. Another training

trick involved having one version of the AI teach another what it was learning about how to most smoothly move the robot's limbs (arxiv.org/abs/2210.10044).

Traditionally, teaching robots to walk and manipulate an arm at the same time has been a "super-hard problem", requiring human engineers to hand-code the robot's

"Teaching robots to walk and manipulate an arm at the same time has been a super-hard problem"

software with knowledge of how its body works and manually tune the robotic movements, says Luis Sentis at the University of Texas at Austin.

Human engineering has enabled Boston Dynamics to create dancing robot dogs capable of opening doors, but an AI-powered approach could make whole-body control much more accessible and affordable for many different robot bodies. "Kudos to the team because they're doing it with a low-cost robot," says Sentis. ■

Jeremy Hsu

Immunology

Hints at how to improve vaccine protection

Christa Lesté-Lasserre

VACCINES that provoke a lengthier immune response might provide longer-lasting protection against infection, due to the way certain immune cells get selected for long-term storage.

Vaccination spurs B cells, a type of immune cell, to produce antibodies against a specific pathogen, such as the influenza virus.

"Immune cells get progressively better at producing specific antibodies"

Most vaccines are designed to create a quick and strong immune response, lasting a few weeks at most. After this, some B cells are stored in the bone marrow as long-lived plasma cells, which provide enduring immunity.

But experiments in mice suggest a lengthier immune response would theoretically allow the most effective B cells to get recruited as plasma cells.

Because immune cells get progressively better at producing specific antibodies, researchers had assumed that the body recruited all its plasma cells from a pool of experienced B cells several weeks after vaccination.

Consequently, many laboratories create vaccines that induce a short, sharp immune response, says David Tarlinton at Monash University in Melbourne, Australia. But this is based on an idea that has never been proven, he says.

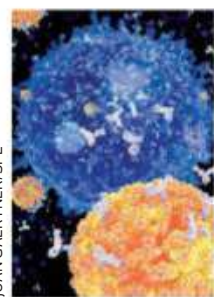
To test this, Tarlinton and his colleagues vaccinated laboratory mice with a standard research antigen and then euthanised them a few weeks later to study the bone marrow

in their legs. The mice had been genetically modified in a way that created a "time stamp" showing when B cells were recruited to become plasma cells.

To their surprise, the researchers found that recruitment didn't just happen at the end of the immune response, but every single day. On average, a new plasma cell was recruited nearly every hour following a vaccination. The longer the immune response lasted, the more plasma cells ended up in the bone marrow (*Science Immunology*, doi.org/gq5hgs).

"This would suggest that the longer you can prolong this immune response, the more antibody-secreting cells you will accumulate, and the best ones will be at the end," says Tarlinton.

This means that vaccines might be more effective if they are designed to trigger months-long, rather than weeks-long, immune responses, he says. That could involve



JUAN GAERTNER/SPL

Illustration of plasma cells producing antibodies against viruses

adjusting the way the vaccine delivers antigens into the body, for example, or adding other substances called adjuvants that modulate the immune response.

For the recipient, the initial inflammation and side effects from such a vaccine would be no different from those that trigger a shorter immune response, says Tarlinton. ■

Genetics

Houseplants modified to mop up pollutants

Michael Le Page

THERE are now two genetically modified versions of the common houseplant known as pothos designed to enhance its ability to reduce indoor air pollution.

In Canada, Origen Air is already selling air purification systems containing a GM pothos. And in the US, Neoplants plans to start selling another GM pothos to consumers towards the end of next year.

Indoor air pollution from cooking, cleaning and materials is a growing concern. Back in 1989, a NASA study found that plants put in sealed chambers containing very high levels of common indoor air pollutants such as benzene and formaldehyde – which can cause cancer – could reduce the levels of these pollutants.

That finding led to the widespread notion that adding houseplants to rooms will lower levels of indoor air pollution, but subsequent studies suggest that the effect is too small to make a difference in people's homes.

So, Stuart Strand at the University of Washington in Seattle decided to enhance the pollution-reducing power of golden pothos (*Epipremnum aureum*) by adding a rabbit gene for a liver enzyme that breaks down a wide range of pollutants. This approach boosted the effect several times. But even so, to make a meaningful difference, Strand concluded that a fan would be needed to move air over the plants.

This GM pothos is now being sold in Canada as part of air purification systems for office buildings that combine high-efficiency particulate air (HEPA) filters with a glass chamber containing the GM pothos. Origen Air has been selling these systems since the second quarter of 2022, says CEO Susan Blanchet.



NEOPLANTS

Neoplants's GM pothos plant could go on sale in the US next year

Now, a start-up company called Neoplants has created another GM pothos with more extensive modifications. It has two added genes from bacteria as well as extra copies of some of the plant's own genes. This enables it to break down benzene, formaldehyde, toluene, ethylbenzene and xylene, the company says.

Tests done in collaboration with the University of Lille in France suggest that the plants are 30 times better at removing these air pollutants than the best plants tested by NASA, says Patrick Torbey of Neoplants. The firm released a paper last week describing its work, but hasn't submitted it to a scientific journal.

"This new paper looks pretty good," says Strand. It isn't possible to directly compare the effectiveness of his GM pothos with the Neoplants one as different tests were done, he says.

It remains unclear whether Neoplants's pothos will make any difference in an actual home. But Torbey says the company is setting up a research facility near Paris that will include two "bedrooms" to test this. ■

Modified insects may curb disease

Brazil has tested male mosquitoes engineered to express a gene that kills off female offspring, which bite and transmit infections, writes **Miriam Fauzia**

MOSQUITOES can spread a range of potentially life-threatening conditions, including dengue, Zika and malaria. Existing methods to control the insects can be inefficient, for example not all at-risk people have access to nets and mosquitoes can develop resistance against insecticides.

Now, Kevin Gorman at the biotechnology firm Oxitec in Abingdon, UK, and his colleagues have genetically modified males of the mosquito species *Aedes aegypti* in a way that dramatically cuts the insect's population.

Across all mosquito species, only females bite. *A. aegypti* females can spread dengue, Zika, chikungunya and yellow fever, among other infections. So the team modified males to create so-called OX5034 mosquitoes.

96%

Maximum drop in mosquito numbers during field trials

These express a gene that allows male offspring to live, but prevents female larvae from surviving to adulthood, unless given an antibiotic antidote.

From May 2018 to April 2019, OX5034 males were released into four densely populated locations in the city of Indaiatuba in the state of São Paulo, Brazil.

Within two of these neighbourhoods, 100 modified mosquitoes were released at a time, while the remaining test areas were exposed to 500 of the insects at a time. These releases occurred three times a week.

Compared with a nearby community that wasn't exposed to any of these mosquitoes, the places where the modified insects were released saw an 88 per cent to 96 per cent dip in their mosquito population from November 2018

L: NELSON YOSHITAKE/SHUTTERSTOCK; R: OXITEC



Left: An *Aedes aegypti* mosquito. Above: A box containing the modified insect eggs

to April 2019, which was the peak breeding season for the insects (*Frontiers in Bioengineering and Biotechnology*, doi.org/jjsw).

The researchers found that releasing 500 modified mosquitoes at a time, as opposed to 100, didn't substantially improve insect suppression.

How long the engineered gene persisted in the local mosquito population depended on the number of mosquito generations that were produced, rather than the initial number of modified males, says Nathan Rose at Oxitec.

Using traps to monitor the mosquitoes, the team saw the gene persist in around half of the surviving male offspring of the modified insects, but disappear after about six generations, over roughly six months. "It was exactly what we expected," says Rose. "We knew that [the gene] would continue for a little while, but we expected it to disappear."

The researchers are particularly focused on controlling dengue. Although usually mild, the infection can be fatal.

Globally, the number of dengue cases has almost doubled in the past three decades, with 100 million to 400 million cases

now occurring annually.

Already endemic in many parts of the world, dengue-carrying mosquitoes may be able to survive and breed in other regions due to climate change.

Since carrying out the study, Oxitec has launched a box-type device throughout Brazil to periodically release modified male mosquitoes. Each box contains the male mosquito eggs. Adding water causes the eggs to hatch after several weeks.

Rose says there are plans to also deploy the boxes in dengue-endemic areas elsewhere, such as in Africa and South-East Asia.

"We knew that the gene would continue for a little while, but we expected it to disappear"

While the study didn't look at whether suppressing the mosquitoes led to a lower incidence of dengue, there is evidence of this happening elsewhere. Similar efforts in Australia, not involving Oxitec, saw fewer cases of locally transmitted dengue compared with previous years. A 2021 study also found a 77 per cent reduction

of dengue in Indonesia after modified mosquitoes were introduced there.

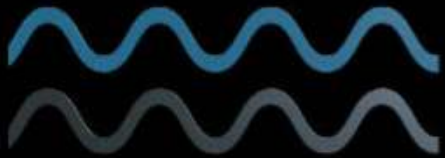
Such approaches have great potential to reduce some infections, but are unlikely to stop transmission completely, says Zachary Adelman at Texas A&M University.

To do so would probably require a multifaceted approach that also cuts human-mosquito interactions, such as installing insect screens on windows and removing standing water, where mosquitoes lay eggs.

According to Dawn Wesson at the Tulane University School of Public Health and Tropical Medicine in New Orleans, Louisiana, Oxitec's effort is a step up from previous insect control strategies in which mosquito sex selection wasn't done via genetic means. "That's the beauty of this method," she says. "You don't have to find all the habitats. You just let the males loose and they find the females [and the gene is passed on]."

As well as dengue, Oxitec is working on developing modified mosquitoes to reduce other infections, such as malaria, says Rose. ■

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Solar system

Mars may still have magma

Seismic studies are revealing details of the Red Planet's finer structure

Jacklin Kwan

MARS is more geologically active than we expected, and it might also have a water table not far below the surface.

The Red Planet is thought to have once been volcanically active, but not for millions of years. Now, by studying a cluster of more than 20 seismic events on Mars using data from NASA's InSight lander mission, Simon Stähler at ETH Zurich in Switzerland and his colleagues have uncovered a likely magma deposit near Cerberus Fossae, a region of fissures created by fault lines.

InSight landed on Mars in 2018 and studies seismic waves there. The speed and frequency of these waves can tell us about the planet's geological structure.

"Now, we have enough data to see certain statistical patterns and we are able to locate quakes happening on Mars," says Stähler.

His team has found that many of the marsquakes, both small and large, originate in the Cerberus Fossae region.

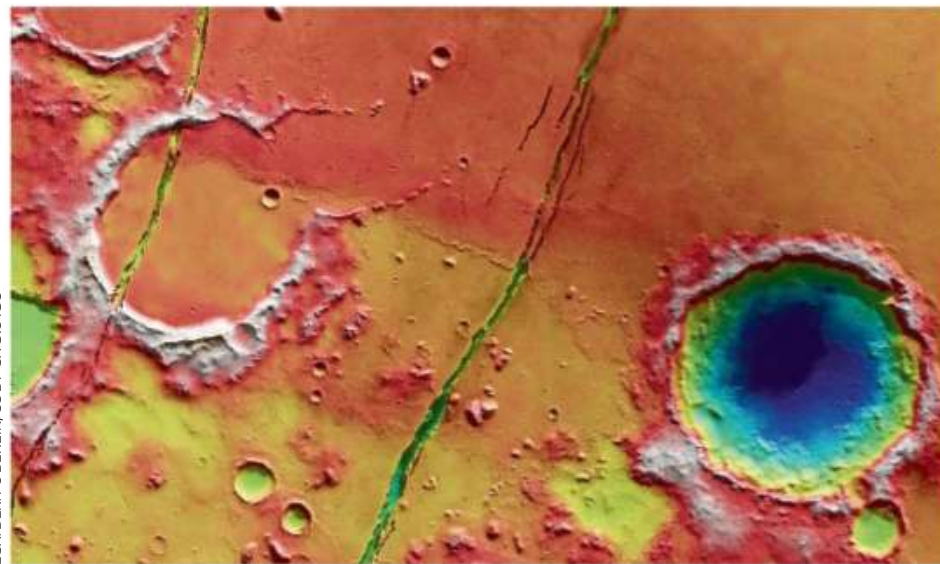
The team suspected magma may be present after analysing the spectral characteristics of

the waves. The low frequencies detected are usually associated with volcanic settings.

"There must be some sort of hot body or magma chamber – so active volcanism – in this specific area," says team member Anna Mittelholz at Harvard University.

The team corroborated the finding with satellite images that show dark deposits of dust in the region, suggesting

Coloured view of Cerberus Fossae on Mars. White is high ground, blue is low



ESA/DLR/FU BERLIN, CC BY-SA 3.0/IGO

volcanic activity in the past 50,000 years (*Nature Astronomy*, doi.org/gq497j).

Many people think of planets as being unchanging over time, says Nick Teanby at the University of Bristol, UK. "I think the exciting thing is that there are these new features on the surface [of Mars] and they could still be active. Mars is still doing things."

More tantalising details have come from tremors that InSight detected from the impacts of two meteorites that struck Mars in December 2021. It is the first time

we have measured seismic waves moving across the surface of another planet.

Doyeon Kim, also at ETH Zurich, and his colleagues say the surface waves coming to the lander from the impact sites were moving faster than expected, at around 3.2 kilometres per second.

Until the impacts, InSight had only been able to study seismic waves from inside Mars. These deep "body waves" showed that the crust beneath the lander was made of three distinct layers.

However, the team's analysis revealed that this structure wasn't representative of the planet as a whole, and the crust that the surface waves were moving through was denser than that under InSight (*Science*, doi.org/gq44kx). "The crustal structure looks really, really different away from the lander," says Kim.

Although the composition of the crust couldn't be established, Kim says a water table beneath Mars's ancient lava flow could have increased the wave velocities, as the presence of water would boost the ground's density. ■

Animal behaviour

Brown centipedes swim by wiggling the 'wrong way'

SOME centipedes don't swim by paddling their many legs, but by wiggling their body from tail to head – the opposite direction of motion that snakes use to cross water.

Kelimar Diaz at the Georgia Institute of Technology and her colleagues used high-speed cameras to observe how brown centipedes (*Lithobius forficatus*) move across the surface of water.

Brown centipedes are found in the UK and North America and don't live up to their name – they have just 28 legs affixed to a body comprising a head and 14 identical segments.

In 32 trials, the team placed a single brown centipede in a tank full of water. These arthropods were too light to dive under the water, but could move across its surface. As each centipede floated, the team saw its legs wiggle a bit, but Diaz says the animals really only moved forward because they were undulating their whole body.

"Snakes and eels do this too, but



SHUTTERSTOCK/NARUPON NIMPAIBOON

Brown centipedes whip their body from tail to head to swim

our centipedes did it the 'wrong way,' says Diaz. The brown centipedes undulated in a motion that began at their tail, while other elongated animals typically shimmy starting from their heads.

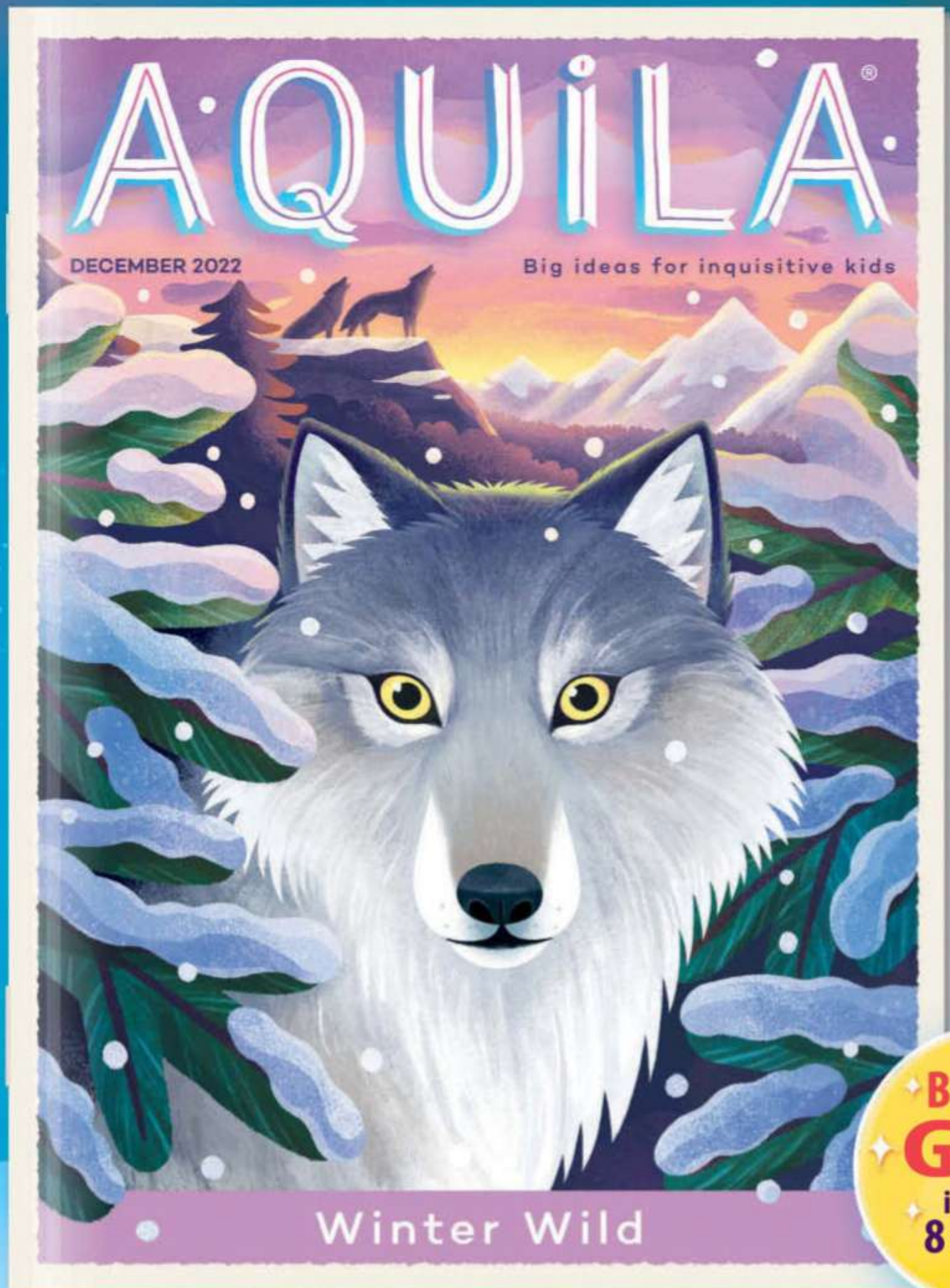
The team made a simplified plastic model of a large segment

of a brown centipede with four legs, and analysed how it interacted with water when dragged. They also modelled all the forces acting on the centipede's body as it swims.

This revealed that the legs affected the drag forces acting on the body in such a way that it was easier for the animal to perform tail-to-head undulations instead of the reverse (*arXiv*, doi.org/jjdt).

In fact, says Diaz, amphibious centipedes tuck their legs in when underwater and swim more like snakes, because they don't experience the same drag effect. ■

Karmela Padavic-Callaghan



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Health

Probiotic helps overweight people lose pounds

Carissa Wong

A PROBIOTIC produces a molecule that mimics an appetite-suppressing hormone, which may help people who are overweight to shed pounds. The molecule, called ClpB, mimics the hormone alpha-MSH.

Pierre Déchelotte at Rouen University Hospital in France and his colleagues advised 212 people with an overweight body mass index on how to reduce their calorie intake by one-fifth for three months. The participants were asked to maintain their usual level of physical activity.

Over the three months, about half the participants also took a probiotic pill containing the gut bacterium *Hafnia alvei* twice a day. The other participants received a placebo.

At the Targeting Microbiota 2022 conference in Paris, France, the team reported that 55 per cent of those on the probiotic lost at least 3 per cent of their weight, compared with 41 per cent of those on the placebo.

Losing this much weight has been linked to a reduced risk of type 2 diabetes and cardiovascular disease in people who are overweight.

The participants taking the probiotic reported a lower appetite during the experiment, compared with those in the placebo group.

It is unknown how food intake could have differed between the two groups, but *H. alvei* may have induced a feeling of fullness that caused these participants to eat less. The researchers also can't rule out the bacterium having affected how fat is broken down.

"This could really help if you want to make a therapy against obesity," says Adèle Rakotonirina at the University of Geneva, Switzerland.

But the effects of probiotics differ depending on our genetics, gut microbiome and overall metabolism, says Rakotonirina. "Ultimately, we would need a personalised approach to prescribe probiotics to minimise any side effects." ■

Environment

Droughts may have kick-started industrial revolution

James Dinneen



FATMANPHOTO/GETTY IMAGES

THE switch from water to coal-powered factories in 19th-century Britain may have been a result of droughts that made water power less reliable and coal more attractive. Previously, it was thought that a lack of suitable locations to build more water wheels was what spurred this industrial revolution.

Historians battle over the precise timing of the transition in Britain from an agrarian economy powered by muscle, wood and water to a manufacturing economy powered by coal. They also disagree about the causes of this industrial revolution.

"Droughts or seasonal irregularities may have made water power less reliable than coal"

One proposed cause is that industrialists ran out of attractive sites along rivers to build the water wheels that powered many of their factories in the late 18th and early 19th centuries. "That implied water was scarce and expensive, and steam and coal was abundant and cheap," says Andreas Malm

A water wheel located in Derbyshire, England

at Lund University in Sweden.

Past analyses of the water power available to early industrialists relied on 20th-century precipitation patterns, but these are unreliable for estimating historical water power, says Tara Jonell at the University of Glasgow in the UK. Jonell and her colleagues used precipitation records starting in 1862 that were collected by what is now the UK Meteorological Office combined with elevation data to create a more accurate model of the flow in Britain's rivers and streams at the time.

The researchers found that industrialists in England, Scotland and Wales had barely tapped potential water power when they made the transition to coal. Concentrated development had saturated a few places, such as the river Spodden near Manchester, but overall "there was still plenty of water power that existed", says Jonell, who presented this work at a meeting of the Geological Society of America in Denver,

Colorado, on 11 October.

This supports the argument that coal power was neither cheaper nor more abundant or more productive than water power at the time, says Brett Christophers at Uppsala University in Sweden. "It adds another nail to the coffin of the old orthodoxy."

One possibility is that a series of droughts or seasonal irregularities may have made water power less reliable than coal, says Jonell. Historical documents discuss drought in Britain in the late 18th and early 19th centuries, though Jonell says it isn't clear whether actual droughts took place at the time or how they might have interacted with other factors.

Malm, who wasn't involved with this work, has previously argued that drought played a role in this transition. He says workers' movements in the 1830s and 40s may have prevented industrialists from relying on labour to make up production shortfalls that could have been driven by changing precipitation patterns. The mobility of coal was also a factor, he says. Relying on coal meant factories could be built near cheap labour or efficient transportation, instead of being limited to sites along rivers.

"Energy transitions aren't primarily about price or supply in the narrow sense, but about other factors," says Malm. He says this is key to understanding today's transition away from fossil fuels.

Robert Allen at New York University says lower rainfall may have been a factor in the transition to coal, but he suspects improvements in steam engines that made them cheaper were more important. ■

Neutron stars may fire neutrino beams like a laser light show

Karmela Padavic-Callaghan

NEUTRON stars may emit most of their neutrinos in just a few beams instead of evenly across their surface. The finding could explain why some of the stars seem to jerk as they spin.

When some massive stars exhaust their fuel, they collapse and become incredibly dense objects made mostly of neutrons. These neutron stars don't produce heat, but can be 60,000°C on the surface. To cool down, instead of emitting light, they emit neutrinos.

Michael Famiano at Western Michigan University and his colleagues used computer calculations to find out whether neutrino emissions occur in a

uniform way across such a star's surface or in a few select locations.

The researchers focused on the crust, which is the outermost kilometre of a neutron star. Here, neutrinos are created either when protons and electrons combine or neutrons decay. Because some of these processes include negatively charged electrons, they are affected by the star's magnetic field.

The researchers found that the magnetic field steers electrons into specific trajectories and constrains where within the crust the most neutrinos are produced. In their calculations, neutrinos only emanated uniformly from the entire surface if the star had a very weak

NASA/CXC/UMIN/REA ET AL; DSS



Neutron stars emit neutrinos as they cool down

magnetic field. For stars with very strong magnetic fields, most neutrinos exited in two large light-show rays at each pole, while for intermediate values it was more varied.

"They can squirt neutrinos out in different directions at different rates," says Famiano. "Or spray the neutrinos in a cone or in a

disc-shaped configuration from the equator."

Areas where the most neutrinos are emitted would cool down faster than the rest of the star, and the temperature difference could cause the crust to crack, he says. Neutrinos are notoriously difficult to detect, so researchers can't directly image how they are radiating out of a neutron star. However, neutron stars have been observed to briefly and jerkily speed up as they spin, which could be related to such cracks forming.

The team presented the work at the autumn meeting of the American Physical Society's Division of Nuclear Physics in New Orleans, Louisiana last week. ■

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Technology

AIs can outperform humans when instructed to think step by step

Chris Stokel-Walker

TELLING artificial intelligence models to “think” step by step when carrying out a task can improve their performance so much that they can outperform humans at jobs AIs usually struggle with.

Using the phrase “let’s think step by step” to cajole AIs into taking more logical decisions was first suggested in a May study presented at a computational neuroscience conference. Such “chain-of-thought” prompting encourages these models to logically consider tasks in the same way that humans do.

Now, Mirac Suzgun at Stanford University in California and his colleagues at Google Research have put chain-of-thought prompting to the test, asking AI models to tackle 23 tasks that

AI historically hasn’t been better than humans at.

The tasks included sorting a list of words into alphabetical order and imagining where you would end up after following a number of navigational steps.

Three different AI models – Codex, InstructGPT and PaLM 540B – were instructed to complete the tasks without any prompting on how to think, and also after being instructed to think step by step.

Prompting the models improved their performance by between about 25 and 32 per cent, on average, across all the tasks.

The results were also compared with how well humans performed each task in experimental conditions. Without the chain-of-thought prompt, the AI models

were only better than humans in between four and six of the 23 tasks, depending on which model was used. With the prompt, the AIs were better than humans in between 10 and 17 of the tasks.

“Chain-of-thought prompting may improve AIs’ performance because it mimics their training”

Prompting made all the AI models perform worse than when unprompted in three tasks. One of these measured sarcasm, while the other two required prior knowledge, such as common presuppositions about how the world works (arxiv.org/abs/2210.09261).

The research shows that using chain-of-thought prompting

works in several different data sets, domains and settings, says William Wang at the University of California, Santa Barbara.

It could prove helpful for GPT-3, a text-generating AI developed by OpenAI. “Moving forward, prompt engineering will still be critical for enabling GPT-3 for different tasks,” says Wang. He believes that chain-of-thought prompting improves AI performance because it mimics the way that the models are trained, by being presented with data sequentially.

“It’s easier to elicit knowledge from large language models this way,” he says. He compares it to how people interact. “For humans, sometimes I also need students to prompt me in a particular order, so it’s easier for me to give them what they need.” ■

Archaeology

US Army bullets found at 1918 massacre site

THE first archaeological investigation of a century-old massacre site at the US-Mexico border has unexpectedly found evidence of US military weapons.

On the morning of 28 January 1918, Texas Rangers and local ranchers rounded up 15 boys and men of Mexican descent from the town of Porvenir, Texas, and shot them execution-style. None of that is disputed. But new evidence suggesting that both civilian and military weapons were used raises questions about whether the soldiers of the US Army’s 8th Cavalry who escorted the rangers may have killed some of the victims.

“The big deal about this is it strongly suggests military involvement,” says David Keller,



JESSICALUTZ

an archaeologist at Sul Ross State University in Texas.

Keller and his colleagues conducted an archaeological survey of the massacre site after being approached by Glenn Justice, a Texas historian. They recovered 13 bullets and bullet fragments, including a bullet containing an

embedded bone fragment – though it is unclear if it came from a human. The archaeologists also found four cartridge casings that would have been ejected from guns after the bullets were fired.

A forensic ballistics analysis identified at least nine or 10 guns used at the massacre site. Contrary

Archaeologists surveying the massacre site at Porvenir, Texas

to expectations, most of the ammunition found was fired from military-issued pistols or rifles (*Journal of Conflict Archaeology*, doi.org/10.1080/13680166.2022.2081111).

While this could mean the US military fired some of the bullets, there is no eyewitness testimony or written evidence to back up the idea, says Miguel Levario at Texas Tech University.

Another possibility is that the Texas Rangers used some military weapons in the massacre. Documents in the Texas State Archives seen by *New Scientist* show that Captain J.M. Fox, head of the Texas Rangers company responsible for the killings, had a contract to purchase weapons from the US Army. ■

Jeremy Hsu

Artificial intelligence

Shutterstock to sell AI-generated art

PHOTO licensing service Shutterstock will begin selling images generated by OpenAI's DALL-E 2 artificial intelligence alongside those created by humans.

A Shutterstock spokesperson told *New Scientist* that the two companies will launch the Shutterstock Contributor Fund to "compensate artists for their contributions" and provide royalties when their intellectual property is used.

The spokesperson also said that the deal that had been struck meant the AI that produces the pictures has been trained only on images from Shutterstock's archives, rather than on content found elsewhere online. The spokesperson said that other people would be unable to upload AI-generated art to its platform.

Matthew Sparkes



ELSA PANCIROLI

Mind

Simple sound can ease nightmares

NIGHTMARES could be reduced by hearing a tone while you sleep that you previously associated with a positive ending to a bad dream during therapy.

The standard treatment for nightmares is image rehearsal therapy (IRT), which involves rehearsing a previous nightmare but changing it to have a more positive ending.

Lampros Perogamvros at the University of Geneva, Switzerland, and his colleagues taught 36 people how to carry out IRT at home, with some listening to a neutral piano tone while they did their IRT. Then over a two-week period, everyone was played the tone when they entered REM sleep.

The group that heard the tone during IRT reported having one-fifth as many nightmares as the IRT-only group (*Current Biology*, doi.org/gq439c). **Alex Wilkins**

Palaeontology

Fossil shows what lizard ancestors looked like

A JURASSIC fossil is helping to illuminate what the ancestors of lizards and snakes looked like more than 167 million years ago.

Found on the Isle of Skye in Scotland in 2016, the 6-centimetre-long skeleton belongs to the species *Bellairsia gracilis*, which was named in 1998 from a smattering of skeletal pieces.

Although it lived at the time of dinosaurs like *Megalosaurus*, palaeontologists initially thought the reptile was a lizard similar to modern species. But thanks to high-resolution scans of the fossil, which is roughly 70 per cent complete, Mateusz Tałanda at the University of Warsaw, Poland, and his colleagues have identified

B. gracilis as a much more primitive reptile (*Nature*, doi.org/jjgq).

Despite its superficially lizard-like appearance, *B. gracilis* represents an older form of reptile closer to the origins of the squamate group, which today includes more than 10,000 species of lizards and snakes, the study found. Palaeontologists call their early ancestors "stem squamates".

The reptile's shoulders and braincase, and the way the skull bones could flex against each other, resemble later squamates, while aspects of the reptile's spine and palate more closely resemble more primitive reptiles from more than 240 million years ago.

The combination of old and new traits indicates that *B. gracilis* was something of a relic from when the first squamates evolved, like the ancestral form still surviving alongside the descendants.

"*Bellairsia* is changing our views on the expansion of lizards in Mesozoic ecosystems," says Tałanda. **Riley Black**

Really brief



MOHAMED EL-SHAHED/GETTY IMAGES

Heatwave impact on poorer countries

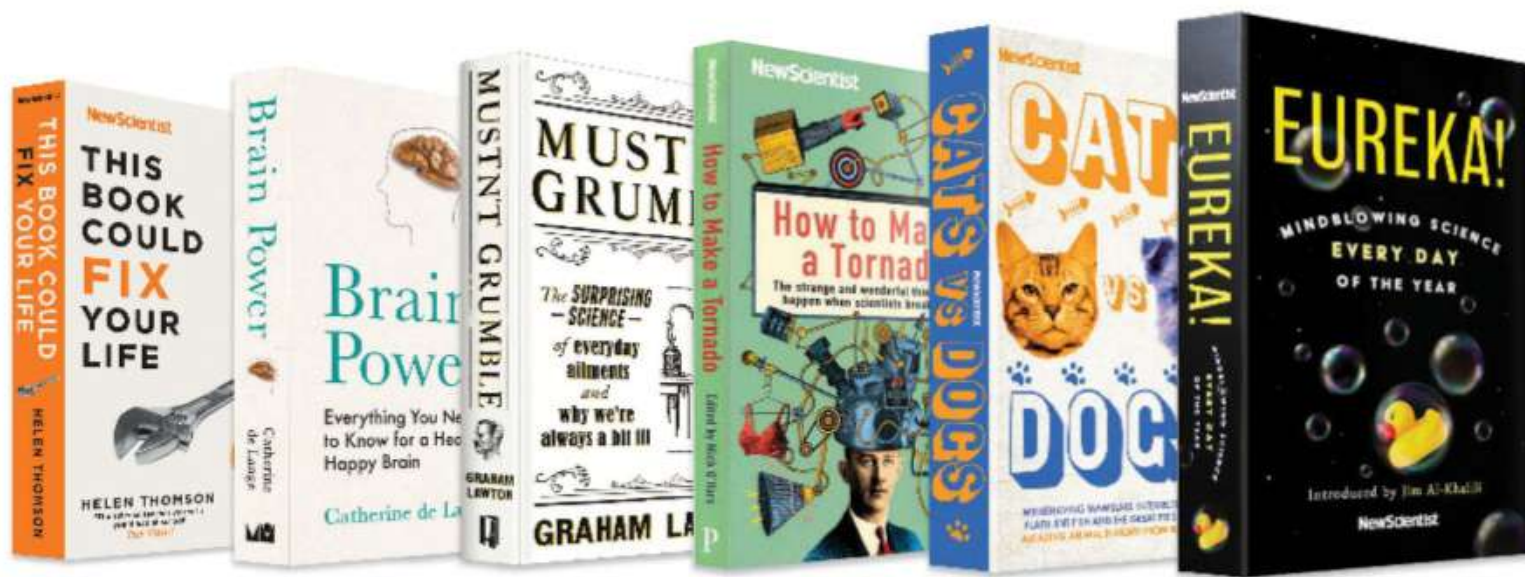
The economic impact of human-driven heatwaves is more severe and unequal than was thought. Periods of extremely hot weather cost the global economy some \$16 trillion between 1992 and 2013, hitting the lowest-income countries four times as hard as the richest ones (*Science Advances*, doi.org/gq5hgq).

Infant mummy gets 'virtual autopsy'

An infant born into an aristocratic Austrian family in the 17th century died overweight, but may have been deficient in vitamin D, according to computed tomography scans of its mummified body. These suggest the child was overfed and underexposed to sunlight (*Frontiers in Medicine*, doi.org/jjgjf).

Bright star is really a strange pulsing core

One of the Milky Way's brightest stars visible to the naked eye, γ Columbae, is actually a stripped-back stellar core. A spectroscopic analysis shows that it lacks carbon but is rich in nitrogen, which is expected for the surface of a recently extinguished core (*Nature Astronomy*, DOI: 10.1038/s41550-022-01809-6).



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Welcome to our Signal Boost project – a page for charitable organisations to get their message out to a global audience, free of charge. Today, a message from **Action on Postpartum Psychosis**



"Immediately following the birth of my gorgeous baby girl was one of the most terrifying, inescapable nightmares I could ever have imagined."
Sally, mum diagnosed with postpartum psychosis

Maternal suicide is the leading cause of death for new mums in the first year after pregnancy

Postpartum psychosis (PP) is the most severe form of postnatal mental illness. 1,400 women are diagnosed with PP each year in the UK - and 140,000 across the world - but many people have never heard of the illness until they or their loved one is affected.

Symptoms can include elation or depression, confusion, anxiety, strange beliefs, hallucinations and suicidal thoughts – and begin in the days following childbirth. PP can get worse very quickly and must be treated as a medical emergency. Most women are admitted to a specialist Mother and Baby Unit for treatment.

With the right treatment, mums with PP make a full recovery but it takes time. It can be difficult for families to find high quality information about the symptoms, causes and treatment.

This is where Action on Postpartum Psychosis comes in. We are the UK charity leading the world in drawing attention to this severe illness. We provide information, support and

advocacy for families affected by PP, train health professionals, and facilitate research into the condition.

Our lived experience network has more than 3,000 members in the UK and throughout the world. Our peer support community saves lives and improves recovery outcomes – and is described as "life changing" and "lifting me from the shadows of a life half-lived".

APP is based in the Institute of Mental Health at Birmingham University and works closely with researchers at Cardiff University and the global academic community to better understand this illness. For more information, visit www.app-network.org.

Want to help?

To reduce maternal deaths, and improve recovery outcomes, we need your help. To support our work, visit: www.bit.ly/APPdonate or get in touch: app@app-network.org. Academic departments or health care institutions interested in partnering on PP research in the UK or globally, please email: research@app-network.org

Need a listening ear?

If you or someone you know is or has been affected by PP, we're here for you. Visit www.app-network.org/peer-support. UK Samaritans: 116123 (samaritans.org).

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Comment

Give solar the green light

The construction of solar plants on farmland in England has come under attack. But a ban would be a grave error, says **Michael Le Page**

ARE fields full of solar panels a blight on England's green and pleasant land? Some figures at the top of the UK government certainly think so.

"I think one of the most depressing sights when you're driving through England is seeing fields that should be full of crops or livestock full of solar panels," said Liz Truss, then UK prime minister, in August. "Agricultural lands... should be used for food production."

This is an issue in many other countries too. China, for instance, is reportedly considering a ban on solar on farmland and in forests.

In England, existing rules already exclude solar farms on the most productive agricultural land. Nevertheless, the UK government was reportedly planning to effectively ban them on most English farmland.

With Rishi Sunak, who has previously criticised solar farms on farmland, now having replaced Truss, it is unclear whether the UK government will pursue this, but opponents of solar on farmland must know three things.

First, a lot of food is being turned into biofuels – even though food-based biofuels increase greenhouse emissions, harm biodiversity and push up food prices.

Second, plants aren't great at capturing solar energy. Crops typically turn less than 1 per cent of the solar energy that hits them into useable biomass, whereas solar panels convert about 20 per cent of light energy into electricity.



SIMONE ROTELLA

Third, farming is very polluting, responsible for a third of global greenhouse gas emissions as well as many other pollutants. In the UK in 2020, 121,000 hectares were used to grow crops for producing heat, electricity or biofuels rather than food. That is five times as much as the 23,000 hectares covered by ground-mounted solar. (Golf courses cover 126,000 hectares.)

To see which is a better use of land, let's compare what we get from solar panels and biofuels. Per year, a hectare of wheat can produce enough bioethanol for a car to drive around

23,000 kilometres, Simon Evans at the climate site Carbon Brief has calculated. For sugar beet, it is 53,000 kilometres.

A hectare of solar, by contrast, can produce enough electricity in a year for an electric car to drive 2,570,000 kilometres. So a hectare of solar gets you 50 to 110 times further – and with much less pollution along the way.

This is why it makes no sense economically or environmentally to ban solar on farms, while continuing to allow farms to grow foods and turn them into biofuels.

Why can't solar just go on roofs, you might ask? There are several

reasons why farmland is often better, from having solar panels facing the right direction at the right angle to the costs of installation and maintenance.

We need to expand renewable capacity as fast as we can to have any chance of stopping the rise in average global temperature from greatly exceeding 1.5°C, not add yet more obstacles.

It is also worth pointing out that the land under solar farms can still be used for some food crops and grazing or managed for wildlife.

That said, when it comes to food, our aim should be to do away with conventional farms. It is estimated that producing food directly from solar electricity – food from air – would let us produce as much protein as we currently get from crops on a tenth of the land. This would have huge environmental benefits, like allowing us to reforest vast areas.

This year, the UK got a glimpse of the future when large parts of the country became parched, temperatures exceeded 40°C (104°F) and wildfires destroyed homes. It is astounding that some leaders still don't seem to grasp that global warming is a far greater threat than a few solar farms. ■

For more on the UK government's environmental policies, see page 28



Michael Le Page is an environment reporter at New Scientist

No Planet B

The real anti-growth coalition The idea environmentalists are part of the Tories' imaginary "anti-growth coalition" is grotesque. All evidence points the other way, says tofu fan **Graham Lawton**



Graham Lawton is a staff writer at New Scientist and author of *Mustn't Grumble: The surprising science of everyday ailments*. You can follow him @grahamlawton

Graham's week

What I'm reading

I have just started *Treacle Walker* by Alan Garner, a Booker prize nominee.

What I'm watching

Ghosts and Mortimer & Whitehouse: Gone Fishing are back on the BBC. Hooray for gentle TV in a turbulent world.

What I'm working on

I'm planning a reporting trip to Uganda. Watch this space.

This column appears monthly. Up next week: Annalee Newitz

LIKE many people in the UK, I found out last month that I am a member of a sinister organisation called the "anti-growth coalition". Our ex-prime minister Liz Truss (who resigned as I was writing this) first used this inane slogan at the Conservative party conference and trotted it out at every opportunity afterwards.

In case you missed it, the coalition includes Remainers, environmentalists, trades union members, protesters and people who live in north London townhouses and appear on the BBC. I tick a lot of those boxes. OK, all of them. (I am also a proud member of our home secretary's "Guardian-reading, tofu-eating wokerati".)

You have to hand it to the Conservatives: they have excelled at coming up with pithy, three-word slogans to get their divisive messages across. But under the hapless Truss, even that dubious skill deserted them. "Anti-growth coalition" is a total dud, like a small child copying the general form of a joke, but not knowing how punchlines work.

It is also grotesquely wrong, especially in its smear on environmentalism. A few days after Truss started tossing the slogan about, I watched an online event run by Green Alliance and Natural England. One speaker was Ian Bateman, an environmental economist at the UK's University of Exeter and a former adviser to seven environment secretaries, including Truss. He poured gallons of high-octane scorn on her flagship "idea". "The UK is in danger of becoming a looking-glass state where protection of the environment is portrayed as 'getting in the way of growth,'" he said. "This view is specious, wrong-headed, outdated nonsense – and it's dangerous.

The economy is totally and utterly dependent on the environment."

Consider the then energy secretary Jacob Rees-Mogg's insistence that the UK "must get every cubic inch of gas out of the North Sea". He then put our money where his mouth is, pledging £90 billion of public money to subsidise fossil fuel exploration on the grounds that it would lower energy bills and is greener than importing gas. This latter claim may be true, but that is besides the point: extracting yet more gas is climate suicide and is economically illiterate. As Bateman pointed out, it takes an average of 15 years

"Jacob Rees-Mogg's £90 billion plan to extract more gas is climate suicide and is economically illiterate"

for a fossil fuel project to go from discovery to production, by which time the world will have moved decisively away from fossil fuels and nobody will want to buy the stuff. It will be £90 billion wasted.

Not to mention the fact that solar and wind power are already cheaper than gas, and that by investing a fraction of that £90 billion in both, the UK could have a green, cheap and secure energy system in a few years.

And yet, another plank of Truss's dash for growth was to ban solar panels on farmland (see page 27), partly because she prefers to look at baa-lambs when driving through the countryside. She evidently doesn't know that sheep farming is a major contributor to greenhouse gas emissions and isn't viable in the UK without anti-free-market government subsidies. Let's hope her successor, Rishi Sunak, takes another tack – as he seems to be

doing over the Tory party's threats to tear up plans to pay farmers to become stewards of nature.

The Environmental Land Management (ELM) scheme was designed to replace the EU's agricultural subsidy system, the Common Agricultural Policy (CAP), a move seen by many pro-Europeans like me as the one positive outcome of Brexit. Under ELM, farmers would be paid for environmentally friendly land management, instead of being subsidised to produce as much food as possible, the costs to nature be damned. That was how CAP worked and it was an environmental catastrophe.

Truss's wrecking crew reportedly wanted to go back to something similar, on the spurious grounds that ELM is a threat to food security. They are presumably unaware that sheep farming in the UK could be viable without subsidies if the animals were reared in newly restored woodland. Baa humbug.

At the online event, Tony Juniper, chair of Natural England, summed it up nicely. "Too many people seem blind to the fact that our economy is a wholly owned subsidiary of nature, with our entire way of life sustained by ecosystems as diverse as soils and the sea. Nature is the basis of our food supply, clean water, air and vital for human health and well-being. Degrading those key services means money has to be spent dealing with the fallout, money that could be better spent elsewhere."

Too many people indeed, and far too many people in positions of power. There is an anti-growth coalition in the UK. It is led by the dinosaurs who think that conserving the environment and economic progress are mutually incompatible. ■

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Editor's pick

Perhaps magnetism helps shape solar systems, too

8 October, p 34

From Erik Foxcroft,

St Albans, Hertfordshire, UK

Stuart Clark's article on how magnetic fields may have shaped some of the largest structures in the universe was fascinating. I have often wondered about the role these fields might play at a smaller scale.

When a new star system is forming, could the magnetic fields in the protoplanetary disc increase the forces between dust particles containing magnetic materials, such as iron and nickel, and help to speed up the formation of planetary cores?

The early balls of dust and rock that clump together would be easily dispersed due to the weakness of their gravitational attraction, but with even a modest magnetic field, those capable of being magnetised would become much harder to pull apart.

Snacking may still be appropriate for some

Leader, 8 October

From Grace Withers,

South Shields, Tyne and Wear, UK

I appreciate the evidence behind doing so, but isn't the labelling of snacking as "dangerous" something of a generalisation? For people with certain illnesses, regular, filling snacks can be easier to digest than eating larger meals and can even improve health.

I understand that the majority of the population has been focused on, but maybe the benefits of snacking should be discussed, too?

More thoughts on green funerals

8 October, p 24

From Andrée Goodson,

Norwich, Norfolk, UK

Heartfelt sympathies to Graham Lawton, and thanks for his article on eco-burials. My mum has stipulated that she wants a

no-frills cremation, as she doesn't want "them b*****s" to profit from her death. We can then scatter her ashes approximately where we scattered those of her beloved husband and dog.

Personally, I would prefer to compost her, then use her on the veg patch. But sadly, this isn't an option in the UK – although it is gaining in popularity in the US.

UK energy policy is fit only for Wonderland

15 October, p 9

From Dave Haskell,

Cardigan, Ceredigion, UK

Due to the calibre of successive UK governments, it is little wonder that energy bills here are going through the roof and that there may be power cuts this winter. UK energy strategy over the years truly appears to have been formulated at the Mad Hatter's tea party.

It is exasperating that the answer is so simple: our politicians need to have more education, skill and experience in science, technology, engineering and mathematics. Worryingly, it isn't just our local representatives who lack STEM degrees, but senior ministers and civil servants, too.

Government and the civil service seem dominated by historians and economists, few of whom have worked outside the political bubble. Without STEM knowledge, it is difficult to even frame the right questions, let alone develop a sensible energy strategy.

We need a way to hold politicians to their pledges

Letters, 15 October

From Geoff Sawers,

Reading, Berkshire, UK

Denis Watkins writes that, until UK voters "elect members

of parliament who are committed to the environment, little will change". This is certainly true, but those politicians must be held to their promises. When David Cameron's Conservative administration was elected in 2010, he pledged it would be "the greenest government ever". But Cameron didn't appear to have much lasting enthusiasm for the cause, and his record on environmental issues was feeble.

More tips in the war against sleeplessness

1 October, p 38

From Chris Donovan,

Albany, Western Australia

Having read your article on insomnia, I would like to share my own experiments with making lifestyle changes in the hours before bed. Bombarding my mind with the pulsating pixels of a computer game, while consuming red wine and cheese, didn't lead to a restful night. Enjoying the warm light reflected by the pages of a book, while eating nothing, did.

From Ellen Fallows,

Kidlington, Oxfordshire, UK

Your article is timely, but lacked detail on the role of hormone replacement therapy as a useful treatment for those experiencing low oestrogen during perimenopause and the menopause. There is good evidence that this treatment can improve sleep quality in such cases.

Down the rabbit hole when it comes to dark matter

3 September, p 28

From Jim Mills,

Avila Beach, California, US

Chanda Prescod-Weinstein's article on her TED talk about

dark matter was very interesting. I like the idea, which she mentions, of dark matter being made up of small black holes. If these black holes were composed of antimatter, it would also explain where all the universe's missing antimatter went.

Of course, you may think that regular matter falling into an antimatter black hole would lead to mutual annihilation of both types of matter, causing them to disappear. But how do we know that there would still be a difference between matter and antimatter in a singularity?

The mutually destructive properties of matter and antimatter could be negated before the two get to meet.

Light our streets with shades of red, please

24 September, p 20

From Sam Edge,

Ringwood, Hampshire, UK

I was interested in the research suggesting that European streetlights are becoming more blue, with all the implications for sleep that this has.

Perhaps when replacing inefficient sodium street lamps with new LEDs, we should be using red ones instead of the RGB LEDs that produce this blue-tinged light? They are cheaper to manufacture anyway.

Could we spot elusive matter in another way?

8 October, p 17

From Tim Stevenson,

Prestwood, Buckinghamshire, UK

You report that large amounts of dark matter may lurk within Earth, and that it bounces off regular, or baryonic, matter – presumably by gravitational action.

Is it possible that the resulting transfer of momentum to baryonic particles might be detectable? The measurements may have to be done at very low temperatures to distinguish this from thermal Brownian motion. ■



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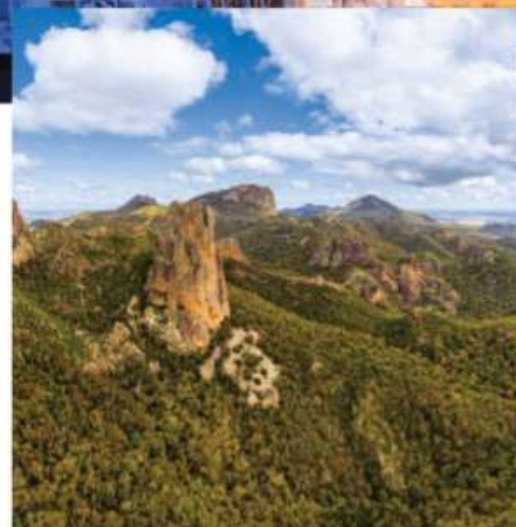
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TIMOTHY NORRIS



Fit for a king



Beyond King Tut National Geographic Society

A HUNDRED years ago, British archaeologist Howard Carter and his workers were exploring tombs in the Valley of the Kings, near Luxor, Egypt. They discovered a plastered-up doorway. This was to prove one of the most spectacular archaeological finds of all time: the tomb of Tutankhamun.

Beyond King Tut: The immersive experience, an exhibition curated by the National Geographic Society, features large-scale projections and animations of some of the 5398 artefacts unearthed.

The largest image, far left, shows Tutankhamun's iconic gold funerary mask, looming large on the two-storey gallery walls. To its right are two pieces of the jewellery found in the tomb: a pendant (top) that depicts Horus, the god of the sky who took the form of a falcon; and a collar made of gold and coloured glass (middle), with a falcon on each end.

A large boat in the centre of the room (bottom right) evokes the ancient Egyptian belief that the dead journeyed by boat to the afterlife.

Beyond King Tut is on display at Pier 36 in New York City until 1 January 2023 and touring cities in the US and Canada. The physical objects from Tutankhamun's tomb are housed in the Grand Egyptian Museum in Cairo. ■

Alexis Wnuk

Secrets of the stones

A fascinating new exhibition tells the story of the cracking of Egypt's hieroglyphic code, finds **Joshua Howgego**



Exhibition

Hieroglyphs: Unlocking ancient Egypt

Sainsbury Exhibitions Gallery, The British Museum, London
Closes 19 February 2023, then tours to selected UK venues

STEPPING from the British Museum's bright main atrium into a darkened space, I am confronted by a huge array of cubes. One face of each cube shows a hieroglyph, which you can rotate to find its meaning. I can see all sorts of symbols, from scarabs, owls and hawks to abstract patterns.

It is fun to explore, but also bewildering, with no obvious link between the symbol and its translation. A snake over an outstretched hand means "to say", while a vulture translates to the letter "a".

The exhibition pays tribute to the enduring appeal of these strange symbols and to the extraordinary feat of their decipherment. Its first section looks at the middle ages, when, for many people, hieroglyphs were imbued with magic and held secret knowledge about the nature of reality.

Take "The Enchanted Basin", a black granite sarcophagus covered in hieroglyphs and discovered in Cairo about 1000 years ago. At the time, it was thought that bathing in this "basin" would cure you of lovesickness. Personally, I find the idea of taking a bath in what is effectively a coffin pretty unsettling, so I move on.

The belief that hieroglyphs held magical knowledge understandably drove people to try to crack the code. In the 1660s, Jesuit scholar Athanasius Kircher attempted to translate



Top: a papyrus containing ancient "spells"; bottom: exploring hieroglyphs



the symbols. Most of his readings were fantasy, but it was fun to discover that he was nicknamed "father of the owls" because hieroglyphs are full of images of these birds. We now know the symbol represents the sound of the letter "m".

"Charnpollion cracked the code because he realised some symbols represented sounds and others ideas"

The transition between this part of the exhibition and the next is marked by one of the world's most famous objects, the Rosetta Stone. Rediscovered in 1799 in Egypt's northern port of Rashid (known to Europeans as Rosetta), it bears an

ancient decree written in three scripts: Demotic, hieroglyphic and ancient Greek. It is amazing to see an object so famous that it now has a second life as a linguistic cliché. The discovery of this stone allowed a direct comparison with known languages. But translation still wasn't easy.

The next part of the exhibition charts the 20-year race to decipherment. We see the work of two key scholars, Thomas Young from England and Jean-François Champollion of France, often in original letters and notes.

It is a complex story and I am not convinced visitors will grasp the finer points. What is clear is that Young made a grave error in assuming that phonetic, sound-based writing is a post-Egyptian artefact, underestimating the

sophistication of ancient Egyptian civilisation. Champollion cracked the hieroglyph code largely because he realised that some symbols represented sounds and others ideas, explaining why some abstract symbols are linked to letters and others to whole words.

So far, I am interested, but not captivated. There are a lot of scraps of papyrus and labels – but frankly there is only so much of that I can focus on. I do enjoy listening to the music in the background, a recording of a hymn sung in Coptic, which creates an ethereal atmosphere and gives us a hint of the soundscape of ancient Egypt. Hieroglyphs gradually evolved into a language called Demotic and then into Coptic, which began to be used in Egypt from around AD 300.

But, for me, the exhibition comes alive in its final section, a smorgasbord of ancient Egyptian artefacts that were only understood once hieroglyphs had been cracked.

The most impressive is a huge "book of the dead", a 4-metre-long papyrus consisting of magical spells and ritual descriptions that belonged to Nedjmet, an ancient Egyptian noblewoman. Its colours, scripts and mythical creatures are so special that I stand in front of it for a full 10 minutes trying to take it all in. It looks almost new – it could be 50 years old, but 30 centuries have passed since it was created.

Back in the bright atrium, I can't help reflecting on how often we underestimate people we don't understand, both in our own time or millennia ago. As Young's mistake shows, for him, the past really was another country. ■

Return of the boy king

After 100 years, the story of Tutankhamun and his tomb still amazes us. Does a new book add much, asks **Jo Marchant**



Book **Tutankhamun and the Tomb that Changed the World**

Bob Brier
Oxford University Press

WE ARE so familiar with the story of the discovery of Tutankhamun's 3300-year-old tomb that it has acquired an almost mythical status. On 26 November 1922, Howard Carter, a British archaeologist, broke through a sealed door under Egypt's Valley of the Kings and poked his candle into the darkness beyond.

Luckily, it can bear repeating, and to coincide with the centenary of the find, Bob Brier retells the tale. A palaeopathologist at Long Island University, New York, Brier is famous for mummifying a human cadaver for a TV show in 1994 (earning him the nickname "Mr Mummy") and the topics of his books range from Egyptomania to obelisks.

His aim is to update the legend. Carter found so many treasures (5398 to be precise), it took a decade to retrieve and document

them. For most of us, writes Brier, the story ends there. But he aims "to form a better picture of the boy king" by reviewing later research.

Brier sets the scene, recounting how centuries after the Giza pyramid complex was built, rulers of Egypt's 18th dynasty hid their tombs in a remote desert valley near Thebes. Excavators in the 19th century discovered a succession of these resting places. By the first world war, most Egyptologists believed there was nothing left, but Carter, sponsored by the super-rich Earl of Carnarvon, was rewarded with Tutankhamun's jam-packed tomb.

Carter set new standards for excavating sites, compiling a stellar team – including engineers and a chemist – and carefully recording finds before carrying them on stretchers to a makeshift lab nearby. But not all his actions stand up to modern scrutiny. Carter and Carnarvon broke into the burial chamber before its official opening and kept several smaller items. In those colonial days, writes Brier, Carter felt he "owned" the tomb.

In October 1925, Carter first glimpsed the king with his golden mask, a spectacle so vivid that "time, measured by the brevity of human life, seemed to lose its common

perspectives". But the body was in a sorry state, effectively glued inside the coffin by oils and unguents that had set solid over millennia.

Researchers have often returned to the bones for X-rays, CT scans and DNA tests, claiming, for instance, that Tutankhamun's parents were siblings. Yet the DNA methods could be contaminated, and CT scans often can't reveal if damage occurred before or after death (see "How did Tutankhamun die?", page 42). Brier conveys this uncertainty, as he writes that examination of the human remains in the tomb seems "cursed" by a host of problems.

But he avoids pinpointing the real problem, that this research is funded by media companies with a vested interest in selling dramatic stories to popular audiences. Perhaps it is a sensitive topic. In 1998, Brier published *The Murder of Tutankhamen* (he used the alternative spelling). It became a bestseller, popularising the now disproven hypothesis that the king was killed by blow to the head.

The picture improves away from the bones, with results such as the otherworldly origins of Tutankhamun's dagger and the possibility of hidden chambers behind the tomb walls. There is also a rundown of research hinting at an active king who may have gone into battle. His chariots had shock-absorbing floors made from leather strips, and he was buried with 32 luxury bows and hundreds of arrows.

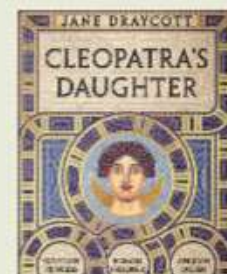
Brier also weaves in thoughtful discussions of how Carter's discovery influenced politics and culture, from inspiring blockbuster exhibitions to fuelling Egyptian nationalism. He doesn't break the new ground he aimed for, but this is an engaging, accessible synthesis. ■

Read Jo Marchant's feature on how technology has transformed Egyptology on page 38



NICK BRUNDLE PHOTOGRAPHY/GETTY IMAGES

Don't miss



Read

Cleopatra's Daughter sees archaeologist Jane Draycott reconstruct the story of a fascinating but long-neglected female ruler: Cleopatra Selene, daughter of Cleopatra VII and the Roman triumvir Mark Antony. On sale from 10 November.



Read

The Complete Tutankhamun is a newly revised, expanded and updated version of Egyptologist Nicholas Reeves's seminal work. He explores what the young pharaoh's tomb means today. Available to buy now.



Read

Egypt's Golden Couple journeys through the revolutionary reign of Tutankhamun's parents, Akhenaten and Nefertiti, who were like gods on Earth. Their story is told by Egyptologists John and Colleen Darnell. Available to buy now.

The TV column

Out of the tomb A pacy documentary does a great job of revealing the latest about Tutankhamun and Howard Carter, who discovered his tomb. It also revives vivid childhood memories of my first encounter with the boy king, says **Bethan Ackerley**



Bethan Ackerley is a subeditor at New Scientist. She loves sci-fi, sitcoms and anything spooky. She is still upset about the ending of *Game of Thrones*. Follow her on Twitter @inkerley



TV
Raiders of the Lost Past With Janina Ramirez: Tutankhamun's Secrets
BBC iPlayer

Bethan also recommends...

TV
Tutankhamun: Secrets of the tomb
Channel 4

Explorer Ella Al-Shamahi digs into the cause of the mysterious deaths among those who entered the boy king's burial chamber.

Film
Secrets of the Saqqara Tomb
James Tovell and Ibrahim Elhefnawy
Netflix

This slick documentary takes us into the tomb of Wahtye, a high-ranking official in the 5th dynasty of Egypt. Proof there is more to Egyptology than pharaoh-bothering.



BBC/ALLEYCATS TV

Presenter Janina Ramirez near Tutankhamun's tomb, Valley of the Kings

in coffee houses. He was ultimately fired from his job as Luxor's chief inspector for antiquities after siding with Egyptian workers who were accosted by drunken tourists.

But Carter was far from enlightened. He benefited immeasurably from local people's knowledge as he tracked down tombs, yet he called them "natives". Like many Egyptologists then, Carter sold some of the treasures he uncovered. He spent a decade meticulously documenting the items in Tutankhamun's tomb, yet there is evidence he gave several artefacts to friends, including a golden collar adorning the king's sarcophagus. Egyptian authorities had stipulated his findings were to remain in Cairo. No amount of affection for Egypt and its history makes up for such a crime.

These are weighty matters, of course. But as its title signals, this documentary series doesn't take itself altogether seriously. We whip through at a merry pace – one minute following Carter as a young inspector, unpicking his detective work as he identifies a prolific tomb raider, and the next, "meeting" Tutankhamun's family via their enduring statues.

Not everyone will enjoy this frenetic style, but there is still a rough chronology to keep viewers' feet on the ground. Crucially, *Tutankhamun's Secrets* doesn't feel overstuffed, though I found myself lamenting that Egyptology isn't the series' sole focus. Overall, the programme did a terrific job not only in revealing more about Tutankhamun and Carter, but in transporting me back in time: to 1330 BC, to 1922, and to the 11-year-old, who was so overwhelmed by a vivid connection to the past. ■

I AM one of those unlucky people who recall little of their childhood. But I do remember, at the age of 11, seeing the Tutankhamun and the Golden Age of the Pharaohs exhibition. It was the first time I felt wonder at the sheer age of the history in front of me, connecting me with the millions who have shared this emotion since Howard Carter and his team discovered Tutankhamun's tomb.

Since then, many falsehoods have sprung up around the pharaoh, his treasures and the man who uncovered them. *Tutankhamun's Secrets*, an episode in the BBC 2 documentary series *Raiders of the Lost Past With Janina Ramirez*, joins a long list of attempts to unravel the myths.

Some are well known, such as the curse that supposedly killed the Earl of Carnarvon, Carter's backer, shortly after the tomb was opened. This, as many viewers will know, was the invention of a rapacious global press. But there are newer revelations.

Like Tutankhamun, Carter has been mythologised, coming to symbolise the wonders of

archaeology without giving any sense of who he really was. While the boy king remains unknowable, his health and reign subject to endless academic contention, unravelling Carter's life is easier.

The son of an artist, he was a sickly child and lived in "genteel poverty", says the show's presenter Janina Ramirez, a historian at the

"Carter benefited from the knowledge of local people as he tracked down tombs, yet he called them 'natives'"

University of Oxford. He shared his father's talent for illustration, which secured him a position as an excavation artist at just 17.

There is plenty to admire about Carter, and plenty to condemn, particularly when it comes to the role of Egyptians in his work. Ramirez explains that Carter took a different approach from his contemporaries: rather than distrusting the people of Cairo and Luxor, he spent his days among them, soaking up their expertise

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Scanning the pharaohs

The lost world of ancient Egypt is coming into sharper focus than ever before as archaeology embraces technology, says **Jo Marchant**

A CENTURY ago this month, Howard Carter opened the tomb of the boy king Tutankhamun. Within, he found ornate jewellery, beautiful furniture, fine clothing – and that famous gold face mask. Everything was in keeping with a royal burial from the most prosperous period in ancient Egyptian history. Or almost everything, because hidden within the mummy's bindings, Carter discovered a dagger that seemed out of place.

The problem wasn't with its golden sheath. It was with its blade of gleaming iron – a metal the Egyptians didn't learn to smelt until centuries after Tutankhamun's death. Carter had a simple explanation. He assumed the dagger was imported, perhaps from the ancient Hittite Empire in Anatolia, where there was an early iron industry. Not until 2016 was it confirmed that the iron originated from much further afield, with the discovery it contains the high levels of nickel associated with meteoric iron. For the Egyptians who wrapped the dagger close to their king's body, it was a gift from the gods.

What makes this finding significant is the way it was made – through an X-ray analysis performed without damaging the dagger. It is indicative of a new approach to Egyptology that emphasises preservation over destruction. Whether it is studying mummies without unwrapping them or generating virtual landscapes as they existed millennia ago, we can now make discoveries Carter could have barely dreamed about while leaving artefacts intact for future generations.

Scanning a mummy is nothing new: X-rays were discovered in 1895, and a few years later,

in 1903, Carter carried the 3300-year-old body of Pharaoh Thutmose IV out of the Egyptian Museum in Cairo and took it by horse-drawn cab to a nearby hospital that had access to the new technology. But recent decades have seen significant changes in the way archaeologists use X-rays, partly because it is now much easier for them to obtain access to high-resolution CT scanners, which fire X-rays from multiple angles to construct a three-dimensional image of an object's internal structure.

Digital unwrapping

In 2021, Zahi Hawass, a former minister of antiquities in Egypt, and Sahar Saleem at Cairo University published the “digital unwrapping” of the mummy of Amenhotep I, a pharaoh who ruled two centuries earlier than Tutankhamun, around 1500 BC. The king's tomb was looted in ancient times, but a few generations later, priests salvaged the body and reburied it for safekeeping. It was discovered in the late 19th century, beautifully preserved inside a coffin that also included flower garlands.

Hawass and Saleem's CT scans showed that the mummy had been carefully repaired. They also revealed 30 pieces of gold, quartz and clay jewellery, with forms including a scarab beetle, snail shell and serpent head, as well as a belt formed of 34 gold beads.

When Carter and his team analysed Tutankhamun's mummy in 1925, they pulled it to pieces in order to discover the objects – including the iron dagger – that had been placed inside. Now, says Hawass, “we can

show you the face, we can show you the golden amulets that we found inside, without touching the mummy”.

Of course, a virtual scan might fail to generate the same sense of awe that can come from directly viewing an ancient object. But many researchers are now going one step further than imaging, using digital scanning data to reconstruct physical objects in exquisite detail with 3D printers. This is sometimes done to engage the public: when Tutankhamun's mummy was deemed too fragile to travel for an international touring exhibition in 2010, for example, the curators printed a realistic copy.

Generating replicas of inaccessible body parts can aid scientific study. In 2018, researchers printed out a mummy's heart to understand how it had been treated by its embalmers. And last year, Egyptologists in Manchester, UK, generated 3D printouts of scanned bones to identify the species inside some ancient Egyptian animal mummies.

Campbell Price, curator of Egypt and Sudan at the Manchester Museum, has used the technique to recreate more items otherwise hidden from view, such as four crocodile skulls bound inside a single mummy. He has even reproduced an embalming plate – used to cover the incision made during the embalming process – revealing a surface decorated with the Eye of Horus, an ancient Egyptian symbol of protection. “You would never have seen or been able to handle these things,” says Price, “but you can with 3D printing.”

New technology can also transform our perspectives of life in ancient Egypt, says



GREATEST OF ALL TIME?

It is hard to rival the 1922 reveal of Tutankhamun's tomb for drama, not to mention the condition, diversity and artistic value of the treasures recovered. But other finds have arguably changed our view of human history in more fundamental ways. *New Scientist* asked archaeologists to nominate their own favourite discoveries.

MYCENAE GRAVE CIRCLE

In the late 19th century, archaeologist Heinrich Schliemann excavated a circle of six royal graves at the citadel of Mycenae in southern Greece. He found a hoard of golden treasures from the 16th century BC, including the "Mask of Agamemnon", which Schliemann believed was worn by Mycenae's mythological ruler, who fought in the Trojan war. That is unlikely, but the find "revolutionised our comprehension of the Mediterranean", says Jack Davis at the University of Cincinnati in Ohio, revealing the previously unknown Aegean civilisations that preceded historical Greece.

TERRACOTTA ARMY

In 1974, workers digging near the city of Xi'an, China, uncovered a life-size clay soldier poised for battle. Archaeologists soon found an entire terracotta army, guarding the tomb of the 3rd-century-BC emperor Qin Shi Huang. Rowan Flad at Harvard University highlights the site along with Yinxi, the last capital of the Shang dynasty. This city, dating to the late 2nd millennium BC, revealed a golden age of early Chinese culture, including palaces, a flood-control system and inscribed oracle bones – the earliest evidence of the Chinese written language. Both "were true discoveries of things and stories that had been long forgotten", says Flad.



The terracotta army comprises thousands of soldiers and hundreds of horses and chariots

HAND AXES OF HOXNE

In 1797, antiquary John Frere wrote to colleagues describing sharpened flints uncovered by brickworkers in Hoxne, England. The stones lay 4 metres deep, alongside the bones of enormous, unknown animals and beneath layers apparently once at the bottom of the sea. Frere suggested they belonged "to a very remote period... even beyond that of the present world". His discovery of what we now know are Palaeolithic hand axes "revealed for the first time the long-term, deep-time human past", says Mike Parker Pearson at University College London, "challenging the biblical notion that the world was created in 4004 BC."

ULUBURUN

This Bronze Age shipwreck, found off the coast of Turkey in 1982, stands as "one of the great underwater discoveries", says Brendan Foley at Lund University in Sweden. Once described as "Wall Street in a ship", it transformed historians' understanding of the era by revealing an astonishing web of trade contacts. The wreck's vast cargo represented at least 11 different cultures and included weapons, jewellery, ostrich eggs, resin, spices and copper ingots from as far afield as Egypt, Cyprus and Asia.

THE FLORES 'HOBBIT'

The shock discovery of diminutive humans who once lived on the Indonesian island of Flores was the "JFK moment" of modern archaeology, says Adam Brumm at Griffith University in Australia, in the sense that scientists in the field still remember where they were when they heard the news. The tiny bones, discovered in a cave in 2003, showed that individuals (subsequently dubbed *Homo floresiensis*) grew to just over 1 metre tall and lived alongside giant lizards. For Brumm, "it was an electrifying and totally unexpected find".

Enrico Ferraris, an Egyptologist and curator at the Egyptian Museum in Turin, Italy. Experts have traditionally focused on texts, he says. "Normally, they put more emphasis on what is written on an object and not what it is made of." This approach has highlighted Egyptian religious beliefs: "eternity, mummies, death and so on", says Ferraris. He argues that science can now offer a more down-to-earth, human insight into this ancient civilisation, such as its manufacturing techniques or how its different artisans worked.

Ferraris has been enlisting scientists around the world to use techniques including mass spectrometry and X-ray fluorescence to re-investigate hundreds of items recovered in 1906 from a 3400-year-old tomb of a high-ranking foreman, Kha, and his wife Merit, located near Luxor in southern Egypt. The team's analysis of a painted box from the tomb revealed that the artist used two different black inks, one to fill in larger areas and one for final touches, such as dots and strokes. Such investigations are "the key to a new chapter in Egyptology", says Ferraris.

Virtual landscapes

What's more, digital approaches are enabling Egyptologists to virtually reconstruct not just tombs and artefacts, but entire landscapes. In a project called Constructing the Sacred, Elaine Sullivan at the University of California, Santa Cruz, has combined data from sources including excavations, satellite imagery and topographic maps to produce a 3D model through time of Saqqara, a sprawling, ancient cemetery just south of Cairo. It is the perfect approach to capture the changing nature of the site over Egypt's entire history, says Sullivan.

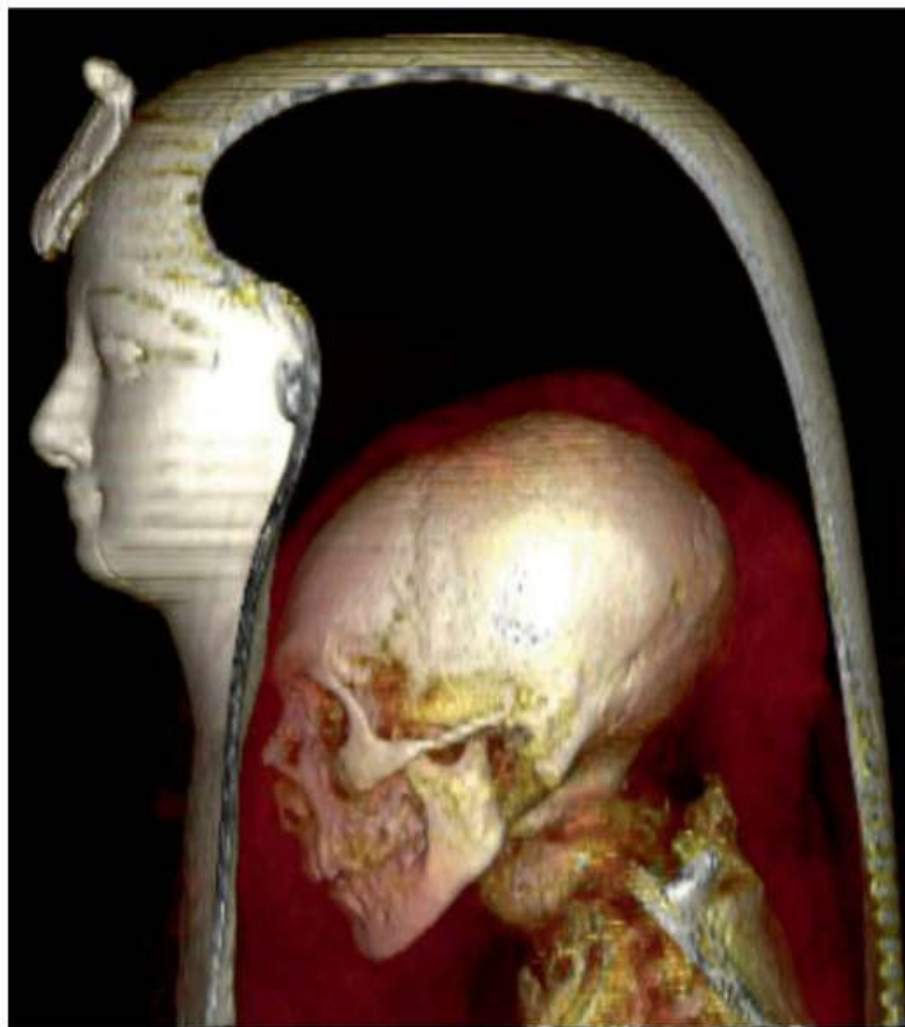
The cemetery developed from a scattering of mud-brick tombs at the edge of the desert in the 1st dynasty, around 3000 BC, to a huge ritual landscape full of pyramids, temples and tombs that persisted until Roman times, roughly 2000 years ago. "I don't think anyone really has a brain that is sophisticated enough to put those hundreds of different buildings back together in your mind," she says. The 3D reconstruction enables "virtual time travel", she adds, so viewers can experience what the site would have looked like at different moments in history.

The model also enables Sullivan to test new ideas, such as sightlines. She argues that



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L: S. SALEEM AND Z. HAWASS; R: APIC/GETTY IMAGES



The recent “digital unwrapping” of Amenhotep 1 (left) involved very different techniques from those Howard Carter used in the 1920s (above)

a previously under-appreciated factor in where people placed their tombs was having an uninterrupted view of monuments that were important to them, such as their pharaoh's pyramid or the Temple of Ptah – an Egyptian deity – at nearby Memphis. She predicts such virtual landscapes will become more realistic as the technology improves. Researchers are already working to reconstruct sounds, smells and lighting effects, while Sullivan and others are delivering their 3D reconstructions via virtual or augmented reality headsets.

A century ago, many of the treasures Carter and his peers uncovered were put inside museum cases. Today's Egyptologists dream of creating virtual worlds where we can walk ancient streets, smell the incense inside grand temples and shiver inside cold tombs.

However, some specialists worry that the science can be pushed too far. Particularly problematic is the imaging and sampling of ancient human remains to look for clues to illnesses or a cause of death. Techniques including X-ray imaging, CT scans and DNA tests have driven TV documentaries and best-selling books, but many scientists

“Egyptologists dream of creating virtual worlds where we can walk ancient streets”

have expressed scepticism over the results (see “How did Tutankhamun die?”, page 42).

Egyptologists including Price are sceptical too. “People think it's this magic wand,” he says. “You wave science and suddenly, bam, you know everything about the mummies.” In practice, however, fragile remains that are thousands of years old and have been through the violent process of mummification are much harder to interpret than living people. Price recalls arguments between doctors and archaeologists when the mummies held by the Manchester Museum were CT scanned at a local children's hospital. “People couldn't decide what they were seeing,” he says.

There is also the ethical question of how or even if to present the results of scans to the public, when it seems unlikely that the ancient individuals would have been comfortable sharing such information; the hieroglyphics and imagery suggest they wanted to be remembered as godlike, not as imperfect, ill humans. For these reasons, the museum's upcoming Golden Mummies of Egypt exhibition, which explores ancient Egyptian beliefs about the afterlife, “will not show any CT scans”, he says. “We are actively editing out information.”

Another researcher who emphasises both the potential and limits of new technology is independent Egyptologist Nicholas Reeves, author of *The Complete Tutankhamun* (see page 35). He studied virtual reconstructions of the painted walls of Tutankhamun's burial chamber, created using laser scans and digital photographs by art conservation company Factum Arte. “It's fantastic,” says Reeves. “It doesn't matter how high on the wall it is, you ➤

HOW DID TUTANKHAMUN DIE?

Few historical figures have been investigated as exhaustively – and brutally – as Tutankhamun. The mummy was unwrapped in November 1925 by anatomist Douglas Derry. He removed the charred, crumbling bandages, cut up the body to remove its jewellery and scraped the pieces from their golden coffin with hot knives. Derry determined that the pharaoh died young, aged around 18. He had a large head, a scab on his left cheek and no obvious cause of death.

That is still about all we can say for sure. In 1968, anatomist Ronald Harrison at the University of Liverpool, UK, X-rayed the mummy for a BBC documentary. He saw a thinning at the base of the skull that “might” have resulted from a blow to the back of the head, a finding that spawned multiple murder hypotheses, but eventually turned out to be an artefact of the imaging process.

In 2005, National Geographic sponsored a team, led by archaeologist and then Secretary General of the Supreme Council of Antiquities in Egypt Zahi Hawass, to CT scan Egypt’s royal mummies, including Tutankhamun. From the resulting 3D images, the team concluded that the king’s left femur was broken and suggested that he fell in a chariot accident. Next, Hawass and his team (now sponsored by rival media company Discovery) attempted to isolate ancient DNA from the bones. In 2010, they reported that Tutankhamun had malaria and that his parents were siblings. They reanalysed the CT scans, identifying that he had a club foot, and presented a new version of the boy king as sickly, inbred and infirm.

These studies inspired more TV documentaries, but were criticised by other scientists, who argued that the DNA results could easily have been due to contamination and that the CT scans couldn’t distinguish between injuries or illnesses from before death and damage inflicted since. Not that this has deterred the speculation: more recent ideas include that Tutankhamun had epilepsy or was felled by a hippo.



MOHAMED ABDEL GHANY/REUTERS/ALAMY

Restoration work in 2019 on some of the artefacts from Tutankhamun’s tomb

can see every brushstroke. You get a better view from sitting down at the desk than you do looking at it face to face.”

Reeves identified previously unseen cracks in the tomb walls, which suggested to him the presence of hidden doorways. He also concluded that several painted scenes of Tutankhamun’s funeral have been altered; he believes they originally showed Tutankhamun in the act of burying an earlier Egyptian royal, Queen Nefertiti. In 2015, Reeves proposed a dramatic hypothesis: that beyond Tutankhamun’s relatively small four-room tomb lies at least one more chamber, the resting place of Nefertiti herself. In other words, Carter’s astonishing discovery a century ago might not be the final word: there may be another, even richer, royal burial to be found.

Technology vs Egyptology?

But that doesn’t mean Reeves thinks this heavy emphasis on scientific tools is problem-free. Since 2015, several teams have probed the walls of Tutankhamun’s tomb with ground-penetrating radar, which uses radar pulses to image buried objects. Detecting chambers cut deep into rock is extremely difficult, however. Researchers were unable to agree on how the data should be interpreted, and without clear confirmation, most scholars have dismissed the Nefertiti idea.

Reeves, however, argues that science shouldn’t simply trump Egyptology. “We automatically assume it’s the last word, but you cannot just ignore the archaeological evidence.” In September, he reported a

further clue from the wall paintings: some hieroglyphics had been altered in antiquity. Although they now depict Tutankhamun’s burial by his successor, Ay, they originally identified the boy king himself burying someone else in this very tomb.

Reeves thinks his hypothesis could be tested by drilling a small hole in one of the tomb’s walls and using a tiny camera to investigate the opening, although whether this would gain approval from the authorities remains an open question.

Despite the controversies, and with the technology improving all the time, some researchers view the data gathered using non-invasive scientific tools as a valuable provision in the event of archaeological finds being damaged. Ultimately, “materiality is fragile”, argues Ferraris. This means physical remains are always at risk from disasters such as flooding, fire or looting.

“We have to do everything to preserve these objects physically, but probably this is not the final goal,” says Ferraris. Digital information, once captured, is unbreakable, a “sort of insurance” that can be studied and appreciated in the future no matter what happens to the objects themselves, he says. “The final goal is the knowledge.” Carter, who spent 10 years meticulously recording the items he found in Tutankhamun’s tomb, would perhaps agree. ■



Jo Marchant is a journalist based in London. Her latest book is *The Human Cosmos: A secret history of the stars* (Canongate, 2020)



One universe, from many

Cosmologist **Laura Mersini-Houghton** says our cosmos is part of a multiverse and there is evidence to prove it. She tells Rowan Hooper about her radical ideas

HOW did our universe begin? This is among the most profound questions of all, and you would be forgiven for thinking it is impossible to answer. But Laura Mersini-Houghton says she has cracked it. A cosmologist at the University of North Carolina at Chapel Hill, she was born and raised under communist dictatorship in Albania, where her father was considered ideologically opposed to the regime and exiled. She later won a Fulbright scholarship to study in the US, forging a career in cosmology in which she has tackled the origins of the universe – and made an extraordinary proposal.

Mersini-Houghton's big idea is that the

universe in its earliest moments can be understood as a quantum wave function – a mathematical description of a haze of possibilities – that gave rise to many diverse universes as well as our own. She has also made predictions about how other universes would leave an imprint upon our own. Those ideas have been controversial, with some physicists arguing that her predictions are invalid. But Mersini-Houghton argues that they have been confirmed by observations of the radiation left over from the big bang, known as the cosmic microwave background.

Here, she tells *New Scientist* about her ideas and her life, which she has described

in her new book *Before the Big Bang: The origins of our universe in the multiverse*.

Rowan Hooper: Let's start with your own story of growing up in Albania. To what extent has that shaped your thinking?

Laura Mersini-Houghton: It's contributed a lot. I was lucky because I had the kind of parents who spotted early on that I was interested in natural sciences and math and then nurtured my interest. Another factor that helped a lot was that my mom worked at a non-profit organisation in Albania called the League of Writers and Artists. I got to spend a lot of time with



composers, writers and artists, and that opened my horizons to spot early on that there is so much joy in creativity.

You talk in your book about how you think of your life in quantum terms; if you hadn't made a particular decision then you would be living a different life. Can you elaborate?

In a quantum universe, everything is based on probability: until you make a measurement on a subatomic particle, all you have are probabilities regarding all possible outcomes. All certainty about the world is gone. Sometimes, during late-night contemplation, I can see parallels between my life in our "classical" world and the quantum world. I can see how my life resembles a quantum world interwoven with uncertainties and unlikely events. If you think of communist Albania, there was a kind of quantum ambiguity where many bad things could happen at any time for no reason at all, certainly not because of your own doing. There is an analogy with the quantum universe, where any outrageous possibility has a non-zero chance to occur.

Getting back to physics, can you explain why our universe is so unlikely and how that led you to think about the multiverse?

It starts with the second law of thermodynamics, which states that the entropy of any system – which roughly means its level of disorder – always increases with time. Therefore, the entropy of our universe at its first moment of existence must have been incredibly small. But the probability of finding a universe that arises spontaneously is directly proportional to its entropy. Since our universe started with a very small entropy, that gives it an exponentially small chance of existing.

We know from observations and theory that the universe started as a very small, smooth patch full of energy, and the Oxford mathematician Roger Penrose found that the chance of starting with the universe like that is 1 chance in 10 to the power 10 to the power 123. So there's almost no chance to spontaneously start with a universe like ours. And that number intrigued me because, well, here we are – we can observe the universe around us. This is our home. We know it exists for sure.

Yet I can't ask the question "why do we have this universe?" if all I am allowed to start with is this universe: I need a pool of possible universes from which I can choose

"I don't think of having copies of myself in other worlds – and I hope there aren't any"

from. So that led me to think that we really need an initial quantum multiverse. That would allow me to meaningfully ask the question of why we got this universe rather than something else.

What do you mean by "an initial quantum multiverse"?

I mean that in the very first moment, before the universe emerged in space-time, you can think of the universe as a wave function in an abstract space of energies.

I began thinking about all this in the early 2000s, around the time that string theory was the leading candidate for a "theory of everything" that unifies gravity with the other three quantum forces to explain our universe. String theory is the idea that nature at a fundamental level is 11 dimensional and particles are actually just the bit we can see of tiny loops of vibrating strings. With string theory, after curling up the extra spatial dimensions to make them sufficiently small to be invisible, you end up with a whole landscape of possible initial energy states, or potential big bang energies, that could start a whole family of different universes.

At the time, string theorists thought this was really bad because they were looking to end up with only one universe – one that looked like ours – described by one theory, and they were ending up with a nearly infinite number of universes. But to me it was great

news because I needed a fundamental theory to provide that pool of energies that would allow me to ask the question, "why did I start with this one rather than something else?"

You had your breakthrough in a coffee shop, and you wrote "QM on the landscape" on a napkin – quantum mechanics on the landscape of string theory. Tell us what you meant.

I had realised something that seems obvious in hindsight. We know for sure that our universe was very small in its first moments of existence. Therefore, it obeys the laws of quantum physics. What dawned on me specifically was that, based on the wave-particle duality of quantum mechanics, I could think of the universe as a wave function instead of as an object. The wave function is the mathematical entity that encodes quantum probabilities. But you can imagine it as a tree made up of many branches, each of which can produce a universe, and it spreads through the energy valleys of the string theory landscape, from where it takes its big bang energy.

Is this where quantum entanglement comes in, the idea that there can be this subtle quantum connection, between the branches?

You get these branches, these many worlds, but you need to decouple them from each other – you need to break that quantum entanglement. Think about when we separate gold from ore. We put the ore mixture into a

NASA, ESA, CSA, AND STSCI





bath of a compound called borax, and since borax interacts differently with different minerals, they start separating from each other. In my hypothesis, the string theory landscape was our borax – it broke the entanglement and separated out the many worlds.

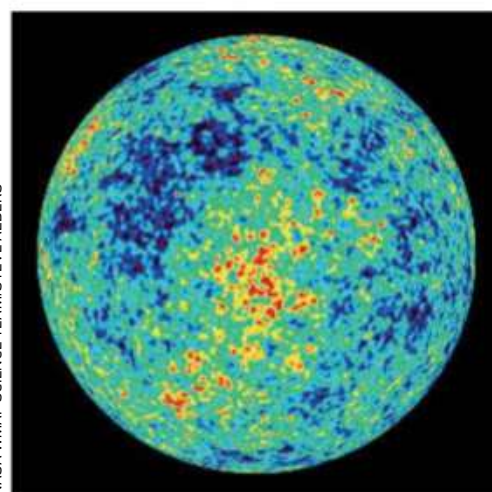
Somehow, early on, our universe went through a quantum-to-classical transition. It became a classical object where each event is determined with certainty. This could not have been the case unless the branches of the wave function of the universe completely decoupled. All the branches decouple as they are going through cosmic inflation. This is the phase, shortly after the big bang, when the universe went through a period of exponential expansion in size. My proposal was that, if this decoupling did happen, we would be able to see the remnants of it in the cosmic microwave background [or CMB], the radiation left over from those first moments of our infant universe. The idea was that, as the branches decoupled, traces of the entanglement would have been left behind.

So you made a testable prediction: that we should be able to see signs of our universe's primordial entanglement with other universes. I made a series of predictions with Richard Holman and Tomo Takahashi in 2005 and 2006. We said we would be able to see signatures of this early entanglement. Our

present universe is just a rescaled version of its infant self, with all its “birthmarks” still there. If you think of all these quantum universes as tiny quantum particles, they were all interacting with each other – gravitationally they were pulling on each other, and that left scars in our sky.

One prediction was the existence of a giant void or cold spot in the CMB. And such a void [about 900 million light years wide] was found in the observations of the Wilkinson Microwave Anisotropy Probe, a space-based observatory. It was confirmed by the Planck satellite, which also observed the CMB. We were the first to show how you can actually

Is there evidence of other universes in the cosmic microwave background?



NASA WMAP SCIENCE TEAM/STEVE ALBERS

To some cosmologists, the existence of our universe is unlikely

test the multiverse and that you don't need to go beyond the universe's observable horizon – you can just see it in our sky.

As you probably expected, your ideas proved controversial. For example, there was an analysis of the CMB data in 2016 that didn't support your conclusions. How have you reacted to the criticism?

I did a new analysis to check the status of my theory using the most recent data from the Planck satellite experiment with cosmologist Eleonora Di Valentino. The series of predictions we made in 2005 for anomalies in the CMB supports the origin of the universe from a quantum landscape multiverse.

There has been a long prejudice against the multiverse. It is an idea that goes back to ancient Hindu and Greek beliefs. But it took a long time to push the idea into mainstream physics. One thing that helped is my proposal to use quantum entanglement as a tool for testing the existence of the multiverse right here, thereby circumventing the speed of light limit constraints. That provided hope that even if we can't see the multiverse directly, we can still indirectly derive evidence and make predictions on where those signatures can be found in our sky.

Max Tegmark at the Massachusetts Institute of Technology has talked of having doppelgangers in other universes when articulating his vision of the multiverse. Would your version of the idea have those?

I don't think there is another Laura out there in some other universe that is my twin or my sister. Once the branches of the wave function have decoupled, they have their own independent existence from each other. So I don't think of having copies of myself in other worlds – and I hope there aren't. If you asked my family, they'd say one eccentric scientist is enough. ■



Rowan Hooper is podcast editor at *New Scientist*. His latest book is *How to Spend a Trillion Dollars*



Feed your immunity

Many foods claim to help your natural defences, but what should you really eat to strengthen your immune system, asks **Kamal Nahas**

IT IS that time of year again. As the cold and flu season hits the northern hemisphere on top of the ongoing ravages of covid-19, many of us reach for something to give our body's defences a helping hand. There is no shortage of foods and drinks that claim to be able to help. Supermarket shelves are heaving with "immunity support" juices, yogurts and spice-infused teas. Comforting, yes, but can these foods really help stave off contagion?

The impact of diet on our natural defences is a topic rife with claims that don't stand up to scrutiny, but we are finally developing a clearer picture of the powerful influence that food can have on our immunity. The surprising truth is that focusing on particular products or ingredients could be leading you down the wrong path. In fact, an immune "boost" might be the last thing you need. Here is a guide to the foods you really should be eating to keep your immune system on top form.

The idea that certain foods can help us when we are ill goes back a long way. Think chicken soup or a drink of hot honey and lemon. Many different plants and plant products, such as spinach, blueberries, garlic, broccoli, cabbage and turmeric, have immune-boosting reputations. In recent years, new concoctions to supposedly help our immune health have been developed at a furious pace. In 2020, nearly 2 per cent of new foods and drinks sold globally made some claim about links to immunity, from "breakfast on the go" smoothies and probiotic yogurts to fermented drinks, such as kefir and kombucha, and so-called functional shots: juices made from ingredients like lime, beetroot and ginger that are designed to impart health benefits.

Numerous claims have also been made on social media for the immune-boosting powers of certain foods, especially in response to the covid-19 pandemic. This has prompted the World Health Organization to issue myth-busting alerts that explain how, for instance, hot peppers in food can't prevent or cure covid-19.

In reality, teasing apart the impact of any food on your immunity is extremely challenging. Many substances that show promise in tests on cells or in lab animals don't measure up in large-scale, real-world trials in people. One reason for this is the complexities of the immune system itself – an intricate network of cells, physical barriers and chemical signals.

Our innate immune system is the first to respond to an invader. It includes general-purpose cells such as macrophages and

neutrophils that patrol the body, detecting and killing bacteria, viruses, fungi and parasites.

The next line of protection is the adaptive immune system, with a more specialised set of defences, such as white blood cells called B-cells and T-cells that learn through exposure to recognise and kill specific invaders. Hordes of immune cells rush to the site of an injury or infection, releasing chemicals called cytokines that recruit even more immune cells. A combination of heat, pain, redness and swelling, known as inflammation, builds at the infected site to aid the healing process.

It is tempting to think that supercharging this system might allow someone with, say, a cold to spring from their sickbed. But many symptoms of infections are actually signs that your immune system is actively working to fight them off. Inflammation can make your throat sore, for instance, and cytokines might trigger a fever to increase the rate of your immune response.

The key to a healthy immune system is to strike a balance between reactivity and restraint. This ensures your body is well equipped to both tackle an infection and avoid too strong a response. "Inflammation is a double-edged sword," says Sung-Wook Hong at the University of Minnesota. To limit unnecessary harm, the immune system must put checks in place. Some cytokines inhibit inflammation, and regulatory immune cells keep reactive ones under control.

If these checks become disrupted, the immune system can attack the body's own cells and proteins, causing autoimmune diseases like rheumatoid arthritis, type 1 diabetes or multiple sclerosis, or can mistakenly react to harmless foreign substances, such as pollen or peanuts, resulting in allergies.

"Garlic, blueberries, turmeric and orange juice have immune-boosting reputations"

But as well as these immune overreactions, there is the increasingly common problem of chronic low-level inflammation, which is linked to accelerated ageing and ailments such as stroke and heart disease. So while it is important to maintain a strong immune system to stave off infection, an ability to dampen it is equally important.

A crucial component of the immune system is the digestive tract. In fact, the gut is the largest immune organ in the body – and it needs to be. Eating is a perilous process that introduces around 100 grams of foreign proteins from plants and animals per day, as well as a myriad of microbes, all of which must be assessed by the immune system to sift the helpful from the harmful.

There are a number of ways that particular foods might be able to support the immune system. The first is via the vitamins and minerals needed for it to function: vitamins A, C, D and E, as well as some of the B vitamins, plus zinc, copper, selenium, magnesium and iron. A deficiency in any of these micronutrients can undermine immune function. And if you read the labels on almost all "immunity" food products, you will see that this claim is due to the nutrients within them that "contribute to the normal function of the immune system" – a factor that has been used to market otherwise unhealthy foods, such as sugary breakfast cereals.

Cynical marketing aside, the question is, if we are consuming the recommended amounts of these nutrients and don't have deficiencies, will extra doses give additional benefits?

Many of us reach for vitamin C – either in pill form or from a glass of orange juice – when we feel a cold coming on, fuelled by an understanding that it helps our body fight the viruses responsible. Yet many studies show ➤

that an extra dose of vitamin C offers no added benefits for someone already eating sufficient quantities, and it is the same story for many of the other nutrients typically added to food products to bolster their “immunity” status.

Immune tuning

More promising is vitamin D, which has recently attracted much attention. This vitamin, found in foods such as egg yolks, liver, red meat and salmon, can “tune the functions of many immune cells”, says Jelena Milenkovic at the University of Niš in Serbia. Around a billion people worldwide are deficient, including 40 per cent of Europeans. Recent studies show how vitamin D reduces the risk of developing an autoimmune disease and can play a role in preventing respiratory infections, although no consistent effect has been found on mortality or requirement for intensive care due to covid-19.

Antioxidants are another factor commonly linked with immunity. These encompass a wide range of compounds, including vitamins C and E, plus plant-based polyphenols such as flavonoids, that can neutralise highly reactive molecules called free radicals. These metabolic products can wreak havoc on our tissues by causing oxidative stress, contributing to disease and ageing.

Although this neutralising power has been demonstrated in numerous lab tests, the health impacts of dietary antioxidants in real-world studies haven’t lived up to their

promise. One explanation is that each dietary antioxidant molecule can only neutralise one free radical, whereas the body produces antioxidant enzymes and each of these can neutralise thousands of them. “The effect of dietary antioxidants inside the cell is trivial compared with antioxidant enzymes,” says Henry Jay Forman at University of California, Merced. This could be a reason why the spice turmeric – one of the world’s most revered immunity foods – and its active ingredient curcumin, an antioxidant, show inconsistent clinical effects in human trials.

These findings pose a puzzle: while it appears that individual products containing high doses of vitamins and antioxidants are unlikely to deliver a health boost, diets rich in these nutrients are linked to healthier immune function. The Mediterranean diet, for instance – replete with antioxidant and vitamin-rich cereals, fruits, legumes, nuts, olive oil and vegetables – dampens down harmful inflammation, whereas the so-called Western diet – rich in sugars and saturated fats, and low in complex carbohydrates, fibre and vegetables – seems to be recognised by the immune system as a threat and is linked with inflammation.

For example, a 2016 trial of 25 adults compared the immune response of a typical Mediterranean meal with a Western style one (pasta, salad, nuts and olive oil vs a burger and fries). The fast food meal led to elevated inflammation and oxidative stress in participants, whereas the Mediterranean one dampened these responses.

Your dietary habits influence the microbes living in your gut



SHUTTERSTOCK/RAWPIXEL.COM

A number of factors could explain these effects. One is that the Mediterranean diet is rich in omega-3, a type of healthy fat found in dairy, fish, nuts, plant oils, seafood and seeds, and contains less omega-6 than a typical Western diet. “This ratio of omega-3 and 6 is associated with lower inflammation, but in Western diets, the ratio is usually flipped,” says Francisco Pérez-Cano at the University of Barcelona in Spain. Another factor is the way that many Western-type meals are prepared. Broiling, frying or roasting processed meat causes sugars to react with proteins, forming by-products that trigger inflammation.

At the heart of these immune effects is our microbiome, the vast bacterial community that resides in our gut. “These communities of bacteria form a delicate ecosystem,” says Fiona Powrie at the University of Oxford.

The intricate details of the interaction between the microbiome and immunity were revealed in a 2020 study of more than 2000 people by a team of researchers led by Joao Xavier at the Memorial Sloan Kettering Cancer Center in New York. This showed how the abundance of different types of immune cells in the blood changed in relation to the presence of different bacterial strains in the gut. For example, a relatively high abundance of the bacterium *Ruminococcus 2* was associated with increased neutrophil levels.

So, by virtue of the close interactions between gut immune cells and the trillions of



SHUTTERSTOCK/VIEW APART

What you eat can make a difference to your immune system



“People consuming fermented foods developed more diverse microbiomes”

these compounds ourselves and eating meals rich in fibre helps to support bacterial populations that can,” says Pérez-Cano.

This takes us back to the question of whether dietary interventions could help tip our immune system in a healthier direction.

To find out, Sonnenburg and his team set up a clinical trial to investigate whether microbiome-targeting diets could modulate the immune system. For this, 39 participants were randomly assigned to a high-fibre diet (adding at least 20 grams of fibre per day to their normal meals) or a diet high in fermented foods (with six servings per day of kimchi, kombucha, yogurt or fermented dairy products). Immune markers such as cytokine levels were monitored, along with the diversity and functioning of gut bacteria.

This study, published last year, found that those consuming fermented foods developed more diverse microbiomes and decreased markers of inflammation. A different pattern was seen in the high-fibre cohort. Although the diversity of their gut microbiome didn’t increase, it was better able to produce SCFAs. Interestingly, the immune response of the participants on a high-fibre diet varied according to the initial diversity of their gut microbes, highlighting the need for a personalised approach for any microbiome interventions.

Gut controller

Another 2021 study, this time of nearly 1000 participants in the UK-based PREDICT-1 nutritional research programme, found that lower levels of markers of chronic inflammation were linked to a high habitual intake of vegetables, but not fruit.

The exact mechanisms of how different species of gut bacteria affect immunity are being elucidated too. Beneficial microbes, such as *Bifidobacterium*, for example, influence immune cells via signals like the SCFAs that they produce. These compounds bind to receptors on immune cells and prompt them to produce cytokines that favour immune restraint over reactivity.

We are now realising that the beneficial effects of antioxidants also seem to be due to the microbiome. Plant-based foods are rich

in polyphenols that were initially thought to dampen inflammation through antioxidant activity. New research, however, suggests that these compounds influence our immune system by favouring the growth of some bacteria over others. For instance, trials in humans showed that consumption of red wine and blueberries, both rich in polyphenols, resulted in an increase in *Bifidobacterium*.

What about short-cutting this process and ingesting the right kind of bacteria for healthy gut function? This idea has fuelled a boom in probiotic supplements – drinks containing live bacteria to fortify our gut microbiome. But just as with vitamin supplements, the efficacy of these products is under question. “The adult gut microbiome is resilient to changes and often prevents probiotic strains from becoming resident in the gut,” says Powrie.

What does all this mean for when you are in the supermarket faced with an array of supposedly immune-boosting products? To keep your natural defences in good shape, what really seems to matter is a healthy gut microbiome. For this, the most important factor is the nature of your overall diet.

“We can try to improve our diets by increasing our intake of fibre and fermented foods to support our microbial populations,” says Sonnenburg. A 2018 study from the American Gut citizen science research programme found that for maximum gut microbiome diversity, we should be eating more than 30 different types of plant a week.

Although a turmeric and beetroot “wellness” shot or a kombucha fermented tea drink contains the kind of ingredients linked to a healthier microbiome, this isn’t going to move the dial if you live mostly on burgers and fries. And watch out for products boasting their immune-support potential when they are really just an unhealthy snack with a few added vitamins. But most of all, remember to nurture the cultures within your gut – they may be key to keeping your immune system in perfect balance. ■



Kamal Nahas has a PhD in pathology from the University of Cambridge and is now at Diamond Light Source, UK

microbes living among them, foods that affect these bacteria may have knock-on effects on our defences. “The foods we choose to eat impact our gut ecology,” says Powrie.

Many modern diets are totally different from the ones humans evolved with over thousands of years. “On evolutionary timescales, we have changed our microbiome in the blink of an eye,” says Justin Sonnenburg at Stanford University in California. He believes the increasingly common inflammatory diseases of the modern world, including diabetes, atherosclerosis and inflammatory bowel disease, may be partly caused by damage to our gut microbiome from consuming a high-fat, low-fibre diet.

One 2015 study, for instance, measured the effects on the microbiome when the typical high-fibre, low-fat diet of 20 rural South African people and low-fibre, high-fat meals of 20 African American people were switched. Within two weeks, a profound change in the participants’ microbiomes was observed, with the Western-style food associated with inflammation of the gut’s mucous lining – a risk factor for the development of colon cancer.

This is one of a number of studies showing how high-fibre foods, such as vegetables, wholegrains and legumes, are key for an immune-healthy microbiome. For instance, the products of fibre fermentation by gut bacteria – short-chain fatty acids (SCFAs), such as butyrate and acetate – are anti-inflammatory. “We can’t digest fibre into



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Stargazing at home

The rainy Hyades

The Hyades is the closest star cluster to Earth, at about 150 light years away. To spot it, first locate Aldebaran, says **Abigail Beall**



Abigail Beall is a features editor at *New Scientist* and author of *The Art of Urban Astronomy* @abbybeall

What you need

Dark skies

A pair of binoculars (optional)

THERE is nothing that marks the passing of the seasons quite like the night sky. When I look up to see the summer triangle shining overhead, it feels like summer here in the UK. The first time I spot Orion lingering over the horizon, I know that the summer is over. And nothing says winter is coming like seeing the Pleiades star cluster while out walking the dog.

The Pleiades is visible from July, so it isn't only a winter feature in my northern hemisphere skies. But in November and December, it starts to twinkle here as soon as the sun has set, lighting up my walk with its distinctive shape, like a tiny rectangle. It sits in the constellation of Taurus, which is visible at this time of year in the east or north-east all over the world, as soon as the sun has set.

The Pleiades, also known as the Seven Sisters, is an open star cluster – a group of young stars that all formed from the same clump of gas and dust – that sits about 440 light years from Earth. Some people refer to the Pleiades as the mini-Plough, because a few of its brightest stars, which can be seen with the naked eye, form a pattern that looks like a tiny version of the Plough, or Big Dipper.

This week, we are looking for another star cluster in Taurus that is great to spot at this time of year. The Hyades, named after weeping nymphs from Greek mythology because its arrival marked the start of the rainy season in Greece, is about 150 light years away and is the closest star cluster to Earth. It sits right in the middle of Taurus,



ALAN DYER/WWPICS/ALAMY

and right in the middle of the Hyades is Aldebaran, the brightest star in Taurus and the 15th brightest in the night sky.

Although it is in the same place in the sky, Aldebaran isn't a part of the Hyades cluster. In fact, this red giant is even closer to us – 65 light years from Earth. But Aldebaran will still help you to spot the Hyades. First, locate the Pleiades, then Betelgeuse, the red giant in Orion's shoulder. Look between these features and you will see the bright star Aldebaran.

Alternatively, you can find the Hyades using Orion's belt. In the northern hemisphere, follow the three stars of Orion's belt from left to right. In the southern hemisphere, go from right to left. Keep this line going until you see a bright star, which

will be Aldebaran. To check you have got it right, keep going and you should see the Pleiades.

In the patch of sky surrounding Aldebaran, you will see the Hyades, a V-shaped group of stars. Because it is so close, it is one of the best clusters to spot individual stars within. Four of these form a group of stars known as the head of the bull, including Epsilon Tauri, the eye of the bull, which is orbited by an exoplanet that is bigger than Jupiter. The four bright stars will be visible even in places with light pollution, but go to a darker sky for a clearer view. You can bring binoculars with you to see many more stars. ■

Stargazing at home
appears every four weeks

Next week

Science of gardening

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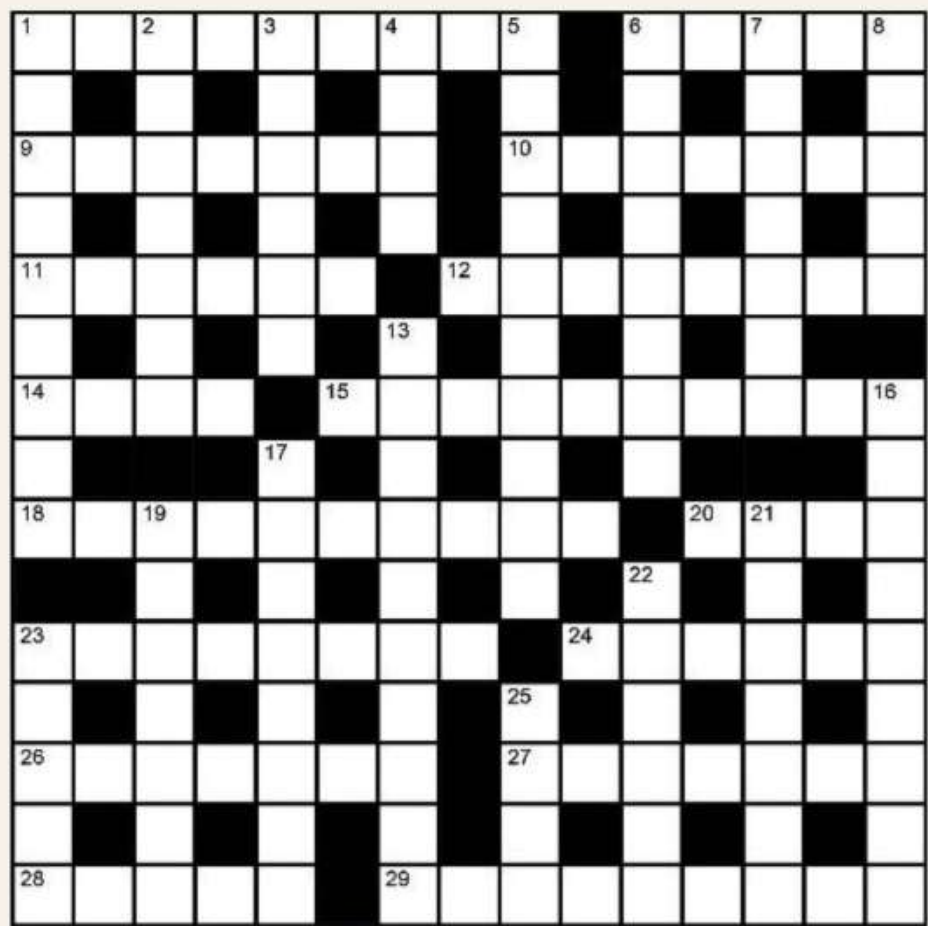
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Quick crossword #120 Set by Richard Smyth



Scribble zone

Answers and the next cryptic crossword next week

ACROSS

- 1** 1999 science-fiction action film (3,6)
6 Slippery bodily secretion (5)
9 Strong offshore ocean current (7)
10 Wax produced by wool-bearing mammals (7)
11 Wood sorrel genus (6)
12 Provision of an unhelpfully large quantity of information (4,4)
14 ___ Corporation, US military think tank (4)
15 Burning (10)
18 Subsequent to childbirth (10)
20 Boil slowly (4)
23 Radical found in fatty acids (8)
24 False; spurious (6)
26 Fruit also called an alligator pear (7)
27 Asian freshwater fish (7)
28 Track; vestige (5)
29 Transmission of energy that may be electromagnetic or α (9)

DOWN

- 1** Aircraft engine (9)
2 Make clear; describe the operations or causes of (7)
3 Neither alkaline nor neutral (6)
4 Coral structure (4)
5 Brilliant synthetic dye (6,4)
6 Small carnivorous mammal in the family Herpestidae (8)
7 Kidney stones (7)
8 Dawn (5)
13 SUV or similar vehicle (4-2-4)
16 Of physics, classical (9)
17 Current; fashionable (2,2,4)
19 Malignant tumour (7)
21 Wave caused by a large, undersea disturbance (7)
22 Openings in a sponge (6)
23 Graph; spreadsheet (5)
25 Grew older (4)

Quick quiz #176

- 1** In megalithic monuments, what name is given to a structure comprised of two large, vertical stones supporting a third, horizontal stone?
- 2** How many people died in the 2003 Columbia disaster?
- 3** What is the world's deepest river?
- 4** The two main groups of carotenoid pigments are carotenes and what?
- 5** Cinnabar is a bright red, naturally occurring form of which compound?

Answers on page 55

Puzzle

set by Howard Williams
#192 Hand over

It was decided that Friendly Co. Ltd and Amicable Co. Ltd would merge and form the Friendly Amicable Co. Ltd. Alas, things have proved less than friendly in the boardroom.

First, there were some angry resignations from the original dozen or so directors at the two companies.

And then, the first board meeting of the new company didn't begin well, with old enmities preventing a group of the board members from shaking hands among themselves. This meant that the number of handshakes was exactly one-third down on the number there would have been if everyone had shaken hands with everyone else.

Let's just hope the share price doesn't go the same way.

How many members are on the new board?

Solution next week



Our crosswords are now solvable online
newscientist.com/crosswords

Cracking stuff

Why do our knuckles and joints make a popping sound when cracked? Does it do us any good or harm?

Nick Vale

Hartley Wintney, Hampshire, UK
I have no idea why popping knuckles makes this noise, but it was established it does no harm back in 1998, an achievement for which Donald Unger won the Ig Nobel medicine prize in 2009.

Every day for 50 years, Unger cracked the knuckles of his left hand, but never his right, and ultimately observed no difference in the function of either hand.

David Nye

Eau Claire, Wisconsin, US
Pulling on the end of a finger produces negative pressure in the joint fluid that fills the knuckle's joint space, causing dissolved gasses to come out of solution rapidly with a pop. This is harmless as long as you don't pull so hard that you damage the joint.

“Researchers used an MRI scanner to watch as people cracked their knuckles, and discovered the cause of the cracking sound”

David Muir

Edinburgh, UK
Old kettles and boilers sometimes produce bangs and pops through cavitation. This is caused by small bubbles of gas suddenly collapsing and propagating a sound.

It was thought that stretching a knuckle caused gas formation through decreased pressure in the joint and the knuckle crack was caused by cavitation as pressure returned to normal.

A study by Gregory Kawchuk at the University of Alberta, Canada, and his colleagues has proved otherwise. They used real-time magnetic resonance imaging to show that the mechanism of joint

cracking is related to cavity formation rather than bubble collapse. Yes, real fingers, attached to real people, were stretched in an MRI scanner.

Cracking occurred during joint separation, with the resulting cavity remaining visible. The knuckle-cracking comes from tribonucleation, the creation of small bubbles by the sudden breaking of contact between solid surfaces (in this case, bone) immersed in liquid (synovial fluid) that contains dissolved gas.

Whether knuckle-cracking is damaging or therapeutic is still to be resolved.

@ManorMill

via Twitter

My son cracks his knuckles all the time. He told me his science



PETER CAVANAGH/ALAMY

This week's new questions

Original me I am 65. Assuming that I still weigh what I did at 25 (I wish!), what percentage of material from 40 years ago remains as part of me today? **Pat Sheil, Sydney, Australia**

Origin of the bang In which direction in the sky did the big bang take place 13.8 billion years ago? **John Miller, Ruthin, Denbighshire, UK**

teacher said it does no harm and is all to do with gas in the joints.

I always believed that knuckle-cracking would encourage arthritis, but apparently, according to his teacher, that is a myth.

@realjohnmurphy

via Twitter

Whether it is a misconception that knuckle-cracking causes arthritis is the subject of some debate.

It seems like it ought to do harm over the long term, simply because wear and tear does harm our joints and intentionally cracking your knuckles is intentionally increasing wear and tear.

Whether the cracking is more harmful than any other wear and tear is another question. I am also a science teacher, for the record.

How much of our 25-year-old bodies remains in us when we are 65?

Running water

How fast would you have to travel to be able to run on water?

Nick Canning

Coleraine, County Londonderry, UK
If I could hit a flat surface of water above a very deep trench at supersonic velocity, such that the impulse of my step was delivered in a time faster than the relaxation time of the water molecules, then the water surface would behave more like that of a solid than a liquid and I would bounce off it.

Unfortunately, humans can't attain such power or reaction speeds. So, unless we use flippers with a large area to displace our weight of water, or we get inside a "zorb" ball, which would allow us to walk across water at a leisurely pace, we will never run across water.

Creatures that can stand or run on water, such as water boatmen, weigh much less than humans, so can use the high surface tension of water to help support themselves. Basilisk lizards also have specially adapted and extendable webbed feet.

@DonStewards

via Twitter

Are we allowed to use custard powder?

Mike Follows

Sutton Coldfield, West Midlands, UK

There are several hoax videos on the internet appearing to show people running on water, but you would need to run at least three times faster than Usain Bolt to make this a reality. Most convincing is the "Liquid Mountaineering" video commissioned by sportswear firm Hi-Tec because the athletes are actually running along a pontoon that floats just below the surface of the water, which moves subtly in response to each footfall.



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Tom Gauld
for *New Scientist*



Insects such as water striders can float, even though they are denser than water. This is because of surface tension, where the surface of water acts like a stretched membrane, which allows a body to float if the ratio of its weight to the perimeter of its contact area with the water is small enough. The surface tension of water is 0.07 newtons per metre. This means a 90-gram basilisk lizard would need hind feet with a diameter of about 4 metres to do the same thing.

Instead, they run on water. Their feet slap the water hard enough that it doesn't have time to flow out of the way. It is almost as if the water momentarily acts like a non-Newtonian fluid and goes stiff. Indeed, the *MythBusters* TV programme mixed 900 litres of water, 450 kilograms of powdered corn starch and a dash of blue dye to demonstrate that it is possible to walk across a non-Newtonian liquid – provided you don't stop.

We would need massless shoes with a diameter of about 2760 metres in order to stand

“Italian researchers won the 2013 physics Ig Nobel prize for demonstrating how humans could run on water”

on one leg without sinking. In 1996, researchers calculated that humans would need to run at 30 metres per second to copy the basilisk lizard and would need to generate 15 times the muscle power available to humans.

Ducks and other web-footed birds run on water with the assistance of lift from their wings. These birds hint at an alternative strategy: run wearing a pair of flippers and reduce the weight of the runner to about 20 per cent of what it is on Earth's surface.

An Italian research group won the 2013 physics Ig Nobel prize for demonstrating this possibility. There is a video showing a runner wearing a harness that supports 80 per cent of his weight while he is furiously splashing water out of a paddling pool in what

turns out to be a successful effort to avoid sinking.

It reminds me of running barefoot on a hot surface. In both cases, the contact time is minimised. However, while people run gingerly on hot sand in a vain effort to minimise the contact force, on water, you need to slap down really hard.

Richard Swifte

Darmstadt, Germany

Wearing ordinary shoes, you would have to run as fast as a cheetah to stay afloat. But many inventors have succeeded in walking on water using various designs of extra large footwear.

In fact, *New Scientist* had a fascinating article on this subject in December 2009. This described the feats of Charles W. Oldrieve, who used 2-metre-long wooden “water shoes”. Over 20 years, Oldrieve achieved fame by walking on rivers. This culminated in 1907, when he won a \$5000 bet by walking 2600 kilometres in 40 days from Cincinnati, Ohio, to New Orleans, Louisiana, along rivers. ■

Answers

Quick quiz #176 *Answers*

- 1 A trilithon, or trilith
- 2 Seven, the space shuttle's entire crew
- 3 The Congo river, which reaches a depth of around 220 metres
- 4 Xanthophylls
- 5 Mercury sulphide

Cryptic crossword **#95** *Answers*

ACROSS 1 Malady, 4 Crocus, 9 Impeach, 10 Betel, 11 Tests, 12 Notices, 13 Tutankhamun, 18 Aileron, 20 Otter, 22 Umami, 23 Epicure, 24 In hand, 25 Thebes

DOWN 1 Moiety, 2/16 Lapis lazuli, 3 Dead Sea, 5 Rabat, 6 Catechu, 7 Splash, 8 Thin-skinned, 14 Unleash, 15 Abolish, 17 Briefs, 19 Reign, 21 Thumb

#191 Sharing is scary *Solution*

Cindy and Ben each ate five sugar drops. To give away half, everyone must have started with an even number. Alice couldn't have started with six or more, because then she would have given three away, and hasn't received anything from Ben. She could have started with four, given two away and received one, but that would make her the only one who ended up with less than they started with, which rules out any possibilities for Cindy and Dan. So, Alice had two, gave away one to Cindy, and got two from Ben, who started with four. Cindy must be the only one who ends up with fewer, so everyone else gains. This leads to Dan starting with six and Cindy eight.

Reptiles in ancient Egypt Twisteddoodles for New Scientist

"Did prehistoric people consider themselves as equals or unequals?" asks a publication from 2020. The question is broader than it may appear. An earlier study by the same scientist suggests that some of those people weren't people. It suggests they were reptiles.

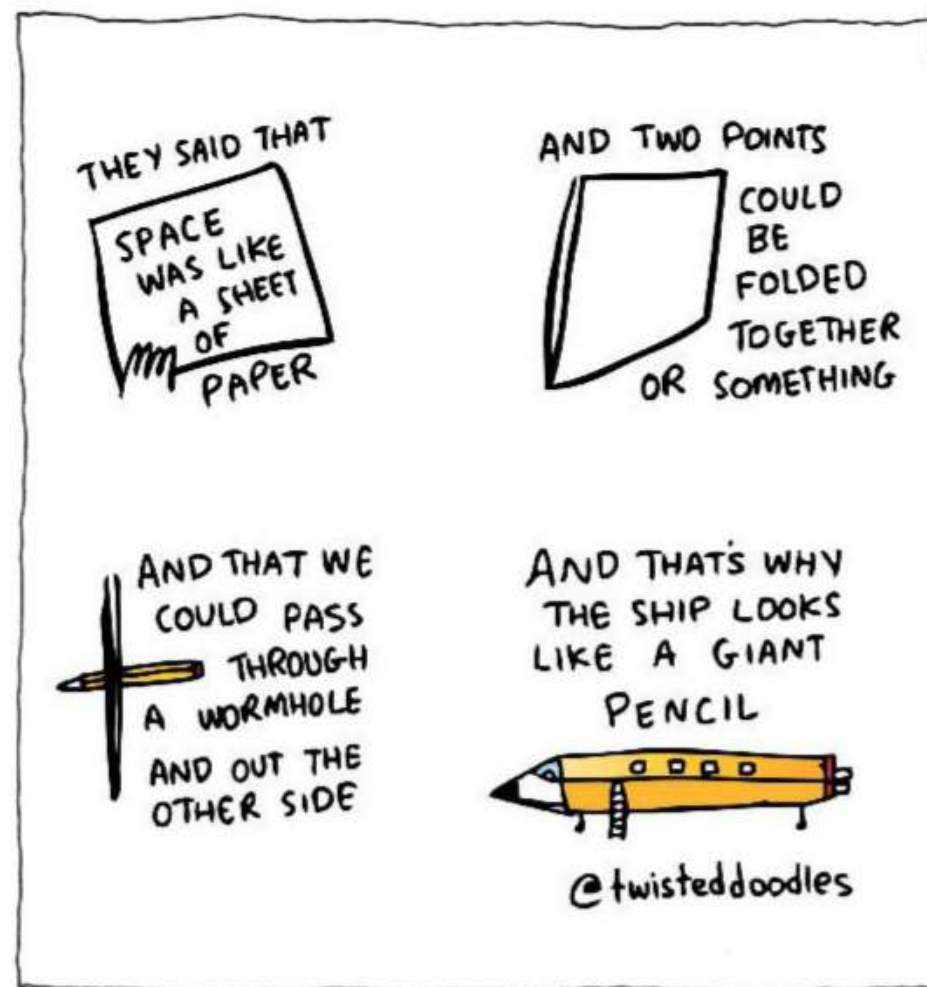
Archaeologist Emmanuelle Honoré at the Free University of Brussels in Belgium studied ancient drawings and paintings found on rocks in south-west Egypt. About 900 of those look like stencilled outlines of hands, but in a report from 2016, Honoré and her colleagues noted that 13 of the hands are "quite tiny". The report, "First identification of non-human stencil hands at Wadi Sūra II (Egypt): A morphometric study for new insights into rock art symbolism", was published in the *Journal of Archaeological Science: Reports*. It says: "Tiny hands have previously been considered to belong to human babies. We challenge this identification... Evidence suggest [sic] that the hand stencils belong to an animal, most probably a reptile."

The researchers reached their conclusion by measuring the tiny-hand drawings and comparing them with the measurements of hands of "living pre-term babies". The tiny "hands", they decided, are probably made by tracing the feet of young lizards or crocodiles.

Honoré's later study sidesteps the earlier reptiles-or-humans question. Its arguments take an on-the-one-hand, on-the-other-hand approach to the equals-or-unequals issue, and make use only of the larger – evidently human – stencil-drawn hands, not the tiny, maybe-reptile extremities (or paws, or whatever). The study's final sentence urges further research, "bearing in mind that different kinds of archaeological evidence can also be in contradiction".

The joys of accounting

Almost by tradition, people assume that accounting is boring. And that accountants are, too.



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Those assumptions may be very wrong. Consider the essay titled "Is accounting becoming too interesting?", which Geoffrey Whittington at the University of Cambridge presented as a lecture in 1995. So intense was the provocation that the paper has since been cited in more than 20 publications – an average of around one citation per year.

Others in the profession argue that accounting and accountants aren't boring enough. And that there is too much floccinaucinihilipilification.

What is this? The answer is plain to anyone who reads the study "Floccinaucinihilipilification in accounting – Does it matter?" by Raymond Chambers at the University of Sydney, published in the *Australian Accounting Review* in 1996 on the heels of Whittington's thunderation.

Chambers explained: "Floccinaucinihilipilification is the habit of treating things as trivial, as of no account... Treating significant differences between things as of no account is the source of much that is confusing, vacuous and fruitless in accounting debate."

Chambers identified three great solecisms that had crept into the professional ways of too many accountants. He thundered: "The third solecism proceeds from the blunders of the first two. It is the fallacy of what Whitehead has called misplaced concreteness." Chambers doesn't identify who Whitehead is or was.

But too much thunder can scare off the young 'uns. Ingrid Jeacle at the University of Edinburgh in the UK analysed the ways big accountancy firms try to attract new hires. They

use recruiting tricks designed to "camouflage the spectre of the stereotype". For details, see her study "Beyond the boring grey: The construction of the colourful accountant".

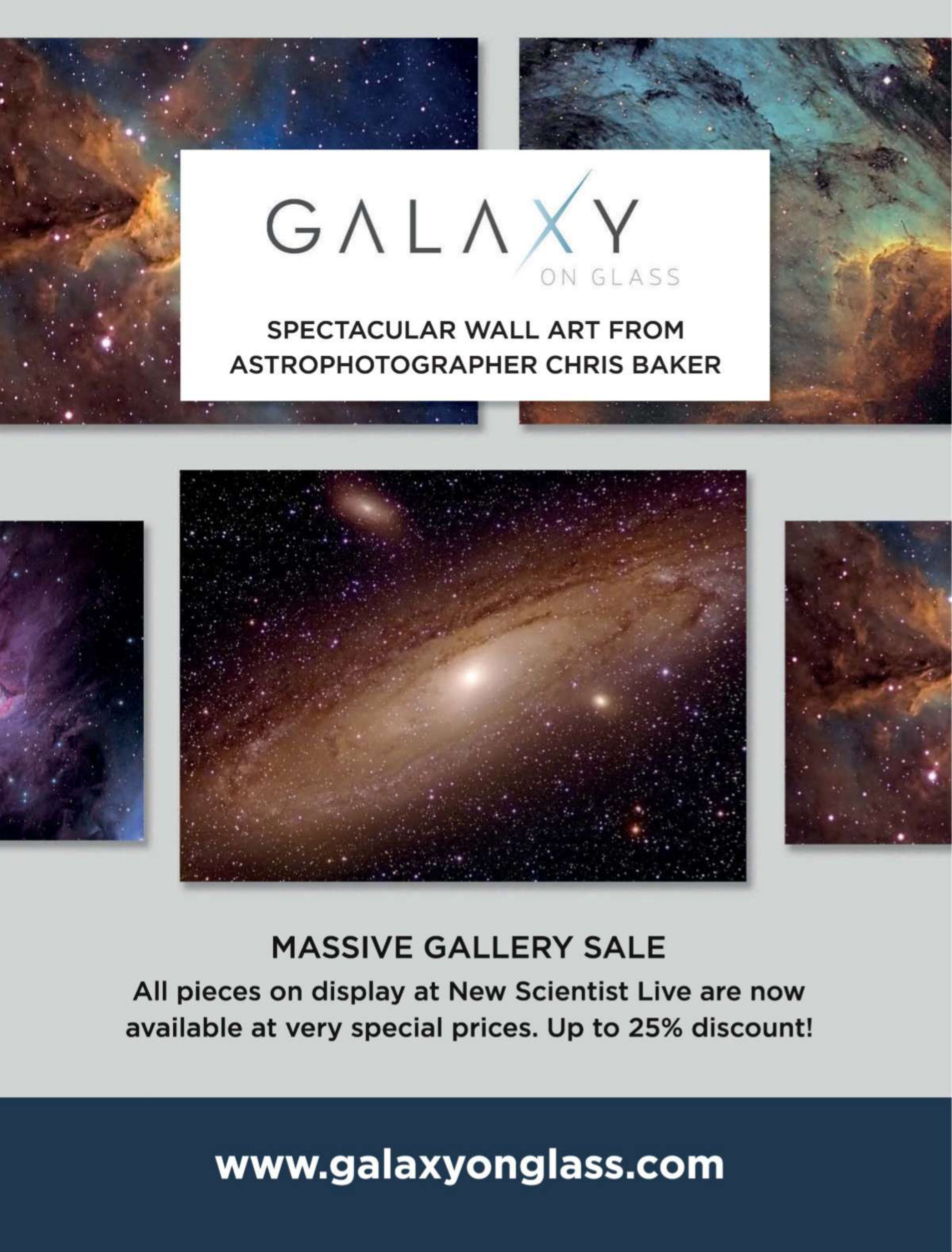
On boredom

Just from their titles, decide whether you want to read these two studies published in the *British Journal of Educational Psychology*: "Boredom begets boredom: An experience sampling study on the impact of teacher boredom on student boredom and motivation" and "Whatever will bore, will bore: The mere anticipation of boredom exacerbates its occurrence in lectures".

After you calm down, decide whether to read this third paper, from the 2018 Annual Meeting of the American Educational Research Association: "Only boring students get bored? A new perspective on academic boredom".

If you knee-jerkily decided no to that one, maybe this will change your mind: here is the final sentence of that paper's abstract. "Overall, recent findings on academic boredom suggest that it is a considerably more complex emotional experience than stereotypically perceived in terms of it being not only highly variable, domain-specific, and situationally dependent, but also consisting of multiple 'boredoms' that vary in both valence and arousal."

The last word on this is a study called "A theory-based psychoeducational video designed to increase knowledge about boredom", by researchers at the University of Alberta and the University of Manitoba in Canada. It is short: one page. The researchers give a clear description of what they did: "we tested changes in students' knowledge about boredom pre-and-post video". Then comes a clear description of what they found: "Our results showed students indicated more knowledge about boredom post-session." That sentence can be read in two ways. ■
Marc Abrahams



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